

4	MAGBOOK	59	60	71	Bot
6			68		72
29			69		
36	51		70		

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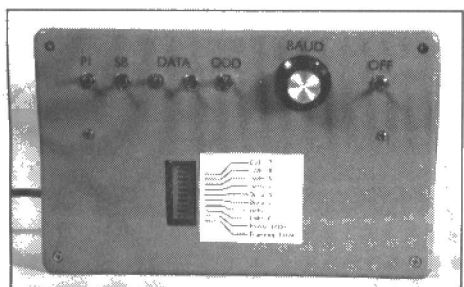
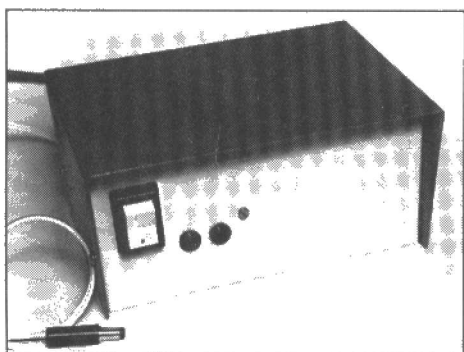
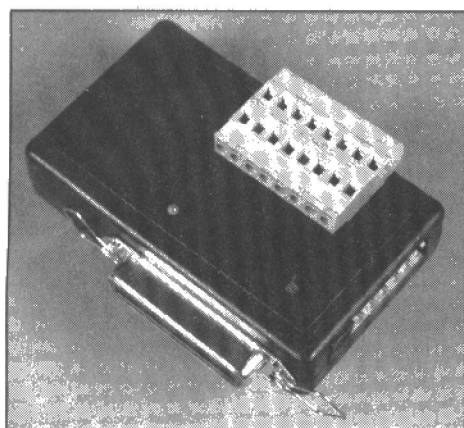
FOR ENTHUSIASTS
BY ENTHUSIASTS
NEXUS

VOLUME 26 No. 2

Contents

Volume 26 No.2

& Features Projects



Return to Mars

11

In this age of science, interest in the meteorites from Mars shows that Mars missions will be a focus of attention for the next ten years, with regular launches planned. Douglas Clarkeson investigates.

Variped - a more Accurate Pedometer

23

Mike Rhodes wasn't Mr. Average, so he build a personal walker's distance counter using a low-cost standard pedometer, an EPROM programmer, and his own stride length.

RS232C Tester

29

Even in these advanced days, interfacing computers through the serial port can be awkward. Robert Penfold's RS232 Tester indicates when the sending device is sending data, and checks the baud rate and word format.

Low-cost Digital Frequency Meter

36

Madlab's PIC-driven DFM uses the Arizona 16C54 PIC to operate between 15Hz to 8MHz with 4-digit accuracy and crystal control, and their article expands on PIC design techniques.

Experimenting With Video (Part 2)

45

In the second part of this new series, Robin Abbott begins a PIC-controlled multipattern video mixer/fader to mix and wipe video patterns.

Centronics Mini-Lab data logger/controller

51

Dr. Pei An's design gathers analogue signals such as temperature or sound level into the computer via the parallel port. The MiniLab's digital I/O lines can be used for high-speed serial data transfer, and the output lines for outside control.

New Lamps for Old

60

Feb up with your torch batteries dying on you? Terry Balbirnie converts a hand lamp that normally uses throw-away batteries to work with rechargeable lead acid types.

Regulars

News

4, 6, 8

Subscriptions

66

PCB foils

68, 69

Practically Speaking

70

Terry Balbirnie talks about the use of high resistance wire to make custom resistor units.

Round the Corner

74



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PCBs at home quicker and easier

Press-n-Peel Etching Supplies Service have produced a new home-build PCB kit which dispenses with the need for special resist-coated copper and exposure to light exposure to transfer the PCB master to copper board. Using a combination of good-quality photocopying and transfers that work with an ordinary domestic iron, Press-n-Peel makes it possible to lift a foil pattern straight from a copper-side paper master (such as the Foil pages of ETI) and transfer it to plain copper board. A dense image is still required for good results (a "grey" photocopy would be unlikely to produce a good result) but the process is less touchy than processing by exposure to light.

Once the master image is printed or photocopied onto the transfer material, a household iron set to around 150 degrees can be used to transfer the image onto clean, lightly-abraded plain copper board, which is then etched in the normal way. Any drop-outs on the transferred image can then be corrected with an Etch resist pen, and the board then etched in the normal way. After etching, the etch resist from the transfer is removed with PnP Stripper, leaving the copper circuit tracks behind.

Press-n-Peel currently produce transfer sheets at £2.50 per sheet in packs of 5 or 10. The company also supplied complete etching kits, including etching chemicals and trays, from £40. They produce a short information leaflet, and can be contacted on Tel. 01722 233043 Fax 01733 231096.

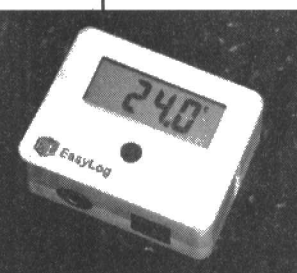
Easy logging

The latest addition to Lascar Electronics' UK-built and designed Easylog range of compact, easy to use data loggers is the EL-2. Handheld and multi-functional, the display module is housed in a small, neat enclosure.

With the addition of an appropriate sensor, EL-2 can measure, display, record and control temperature, voltage, current, humidity, pH, frequency and rate count. The unit is configured using Windows-based control software package EL-WIN. Data stored in the module can be saved and graphically preserved using EL-WIN's graphic function, or exported to various popular spreadsheets.

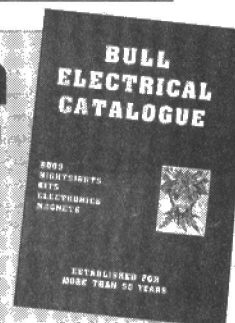
EL-2 can be used as a stand-alone data logger, or be permanently connected within a system. Up to eight EL-2s can be connected together to build up more complex systems. Each module has non-volatile memory for up to 8,000 readings, and a 3.6V longlife lithium battery. The display is a 3.5-digit LCD.

For more information contact Lascar Electronics, Module House, Whiteparish, Salisbury, Wilts SP5 2SJ Tel 01794 884567 Fax 01794 884616.



Bull hits town with colour catalogue!

Bull Electrical have replaced their regular newsletter this time by a 31-page colour catalogue illustrating many of their exotic and practical gadgets and devices. For instance - a Russian Analyt microscope and live shrimp farm for £27; a Newtonian reflector telescope for £249; the Amazing Forty Foot Long Giant Bubble Blowing Kit for £12; a Hypothermia Space Blanket for £4; Magnetic Marbles for £3.99; lightsticks for fun or emergency, £6 for two; fruit-powered digital clock/calendar £9.95; colour video cameras for security and monitoring £119; Night Sight units of a number of styles and prices; handheld satellite navigation for walkers, fishers, etc. £179 and many more (all prices ex. VAT), all clearly illustrated in colour, with ordering details, terms of trade (minimum orders, carriage charges, VAT etc.) and order form at the rear. The rear cover features a colour map of how to find Bull in their home base of Hove. But mark it on your road map before you send your orders in! Bull Electrical Tel. 01273 323077. See this issue for further details.



HOBBY BOOK AND MAGAZINE TROVE

Magtrack is a service that locates back issues of specialist magazines. Owners Hobbyists Bookland now stock over 350 different titles, and as many as 120,000 individual issues, in electronics and radio, transport, antiques, aviation, shipping, model engineering and railways among others. Magtrack monitors incoming purchases on the store's computer and checks them against customers' wants lists constantly. Hobbyists Bookland also stocks 20,000 books and welcomes visitors.

Visitors can find Hobbyists Bookland at The Fosse, Fosse Way, Radford Semele, Leamington Spa, Warwickshire CV31 1XN Tel 01926 614101 Fax 01926 614293 email 100544.1675@comuserve.com

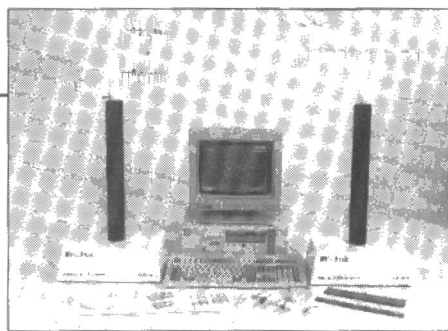
Model antenna test set

The 57-100 Feedback Antenna Modelling System has been designed and manufactured by Feedback Instruments to enable lecturers and trainers to provide hands-on demonstrations of the principles of antenna design. Using the System it is possible to construct and test most common types of antennae: monopole, dipole, yagi, log periodic and stacked and bayed yagis are among the examples.

The 57-100 can also be used as a research tool for commercial research and development and for educational use at all levels from technician training to post-graduate study, says Feedback Instruments Marketing Manager Eric Tucker, himself a former university lecturer in electronics.

The Modelling System consists of two towers around 1 metre in height, one of which is a low-power transmitter in the 1.2 to 1.8 GHz range, controlled by a frequency synthesiser with motorised rotation of the antenna. The rotation mechanism includes an encoder capable of supplying digital data on the degree of rotation to a PC, which is running appropriate antenna design and analysis software.

The user can mount the antenna system under development (or to be investigated) at the top of the tower. The system is



supplied with a range of components (see the photograph) which make it possible either to put together

most common antennae, or to configure a new kind of antenna according to the user's design, using system or new components.

The second tower contains a receiver controlled by a frequency synthesiser which produces a DC output representing the received signal intensity. To achieve parity of results, the 4x log periodic array on the receiver tower would remain constant. The two towers are linked by a 5-metre multiway cable carrying power and data. A similar cable links the transmitter tower to the PC.

Measurements are logged and the results plotted by software running on the PC, which gives detailed graphic displays. An E&H plane 3-D polar plot display provided a picture of the directivity of the antenna under test. Gain, VSWR and return loss can also be displayed over the frequency range.

For more information, contact Feedback Instruments Ltd., Park Road, Crowborough, East Sussex TN6 2QR, UK. Tel 01892 653322 Fax 01892 663719.

PUBLIC CAMPAIGN FIGHTS TECHNO-FEAR

The UK Government has launched a new "awareness campaign" to banish technofear from Britain in time for the millennium as part of its Information Society Initiative.

High street shops, businesses and voluntary organisations are linking up with the Government in a new campaign called "IT for All". The Government has found that research shows that 55 per cent of the population are either interested by information technology, or actively reject it. Some people are unconvinced of its usefulness and suspect current developments of being fads that will die out before it becomes really useful. Others are afraid that information technology is too difficult for them to learn to use effectively, or that it may be used to violate the privacy of individuals and organisations.

Prime Minister John Major said, in connection with the initiative: "Society can now be more open and communicative than ever before. But there are barriers to be overcome. Fear of the unknown. Suspicion of the new. Many people see IT as too complicated, full of jargon, not for them. We must overcome those barriers or get left behind."

President of the Board of Trade Ian Lang said: "We want people to try computers, to experience on-line services, and to do this where they feel most comfortable: at home, in libraries, on the high street and in shops. Britain must make the most of IT."

High street traders like Dixons, the Woolwich building society, and supermarket chain Safeway have joined technology

based businesses like British Telecom, IBM, Mitsubishi, ICL, Microsoft and Motorola, and voluntary and public service organisations like the British Deaf Association and the British Library to support the Government's move.

Vowing to "provide hands on opportunities across the country for people to try out for themselves technology applications, including the Internet, e-mail, touch screen information terminals and personal computers", it is to be hoped that opportunities will come to accessible locations all over Britain. Electrical store Dixons, in particular, have announced that they are planning a touring Cyberbus, and open evenings in stores for parents of school pupils. Microsoft expect to bring technology nights to schools for parents and children. Some libraries should become the scene of IT tuition for novices, sponsored by local companies.

Local Business Links will be a vehicle for providing businesses with advice on how to apply the new technologies. Bidding to make information technology easier to understand, the Information Society Initiative (ISI) aims to remove fear of Information and Communication Technologies (ICTs) for the 21st century.

MODSMODSMODSMODSMODSMODS

The PCB foil pattern for the **Cable Break Tester** (January 1997) appears on the PCB foils page in this issue. The power supply foil pattern for the Giant Bargraph Light Show appeared over the "Cable Tester" label in the January issue.

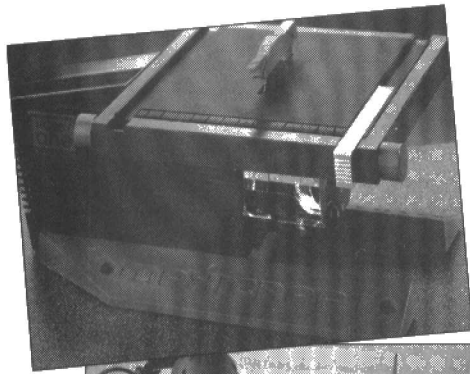
Farnell extend their semiconductor catalogue

Farnell Components has added 1100 new semiconductor and opto-electronics products to the winter edition of its 15,000-product semiconductor catalogue and 11,000-product CD-rom, and launched the second volume. The CD-rom also provides access to data sheets for many of the devices. Pricing is current to 31 March 1997. Farnell's UK MD commented: "Through customer feedback we discovered that a CD-rom containing semiconductor data sheets was something the industry needed to make selection of ordering of products much less time consuming." Commented a user: "They are right, as well. No matter how good a catalogue is, lack of data sheets can slow down designers who do not carry the full library of manufacturers' data books, so quicker access to their product data by a reliable supplier like Farnell is an advantage."

For Web users, information about Farnell can be found at <http://www.farnell.co.uk>, or enquire at Sales number 0113 263 6311. Semiconductor catalogue reference 790825, CD-rom 790837. Farnell runs a minimum order system.

EURO HOBBY TOOLS COME TO UK MARKET

UK specialist hobby, craft and DIY toolmakers Minicraft have joined forces with their opposite numbers in France, Maxicraft, to launch three new 230 volt Maxicraft tools on the UK market: a flexible power tool, a bench circular saw, and a hot wire cutter.

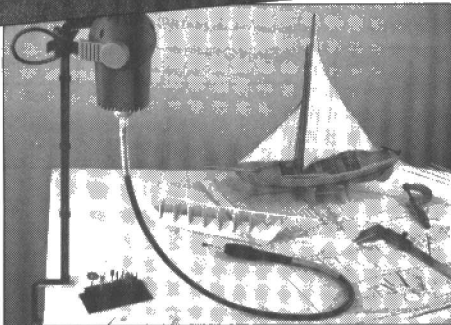


The 230V flexible power tool (No. 75002, RRP £149.99) is a 90 watt mains motor power tool with a 1-metre flexible drive for working in hard-to-reach positions. The tool has a foot-operated variable speed control operating from 3,000 to 14,000 rpm, and 15 accessories for drilling, sanding, polishing, grinding and cutting. The flexible drive is fitted with a curve-limiting spring to prevent strain damage and give longer life. The motor comes with an extendible suspension column to lift the motor clear and the bench, maximising working space. The Flexible power tool can also be used with Minicraft collets, and with drills fitting Minicraft accessories.

The bench circular saw (No. 40600, RRP £99.99) is a 90 watt saw for cutting metal (with a cutting capacity of 3mm for soft metals, 1.5 mm for hard metals), wood (10mm softwood, 8mm hardwood), plastics (5mm) and laminates. There is a rip fence to facilitate precise straight cuts, and the blade has a cutout system and blade guard for extra safety. There is also a vacuum cleaner outlet and sawdust pan. Working table dimensions are 1880mm x 180mm, and the standard blade is a wood cutting blade. The bench saw can be used with Minicraft 50 and 60mm saw blades for various applications.

The hot wire cutter (No. 43900, RRP £99.99) is designed to cut shapes and contours in expandable polystyrene and thin plastics. This is a versatile temperature-regulated tool designed for detailed cutting work, suitable for aero- and boat modelling, prototype work, architectural models, etc. The cutting capacity is 200mm on the specified materials. The work table dimensions, as for the bench saw, are 180mm square, and the unit comes with a 2m roll of 0.2 heat resistant cutting wire. Extra wire is available.

For more information contact Minicraft, 1&2 Enterprise City, Meadowfield Avenue, Spennymoor, Co. Durham DL16 6JF. Tel 01388 420535.

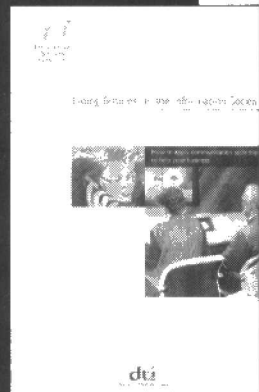


Information technology in business from the DTI

The DTI has released a series of booklets to help small and medium sized businesses make practical decisions about which new technologies to opt for and how to use them.

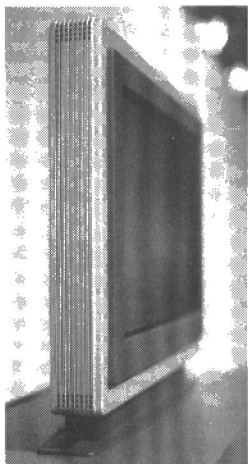
The original publication, released earlier this year, is *Doing Business in the Information Society*, is a substantial information booklet that gives outline explanations of the Internet/World Wide Web, Networking, email, Electronic Data Interchange (EDI), CD-ROMs, Videoconferencing/ ISDN, and mobile communications. There is also a section on how businesses might apply these developing technologies to their needs, and a contact list at the back.

Following *Doing Business in the Information Society*, the DTI has produced seven "implementation guides", covering the above technical subjects in greater detail. The emphasis is on choosing the right system for the job and finding a reliable supplier, rather than advanced technical details. These publications can be obtained free by calling the ISI (Information Society Initiative) Infoline Tel 0345 152000.



Flat television gets one step closer to the wall ...

Sony have launched a large screen flat colour television in Japan in time for Christmas.



The model PZ-2500 has a flat panel display screen, code-named "Plasmatron", giving high brightness and high contrast. Because Plasmatron the display panel is flat and has no cathode ray tube, the monitor portion of the screen is only 132 mm thick, measuring in at 242 mm when the base stand is added.

The PZ-2500 also has a high resolution multipoint-scanning system that gives the display compatibility with various types of input signals, including NTSC broadcast, high definition and VGA-mode personal computer signals. The Plasmatron panel was developed by Sony on the basis of Plasma Addressed Liquid Crystal (PALC) technology developed jointly with US firm Tektronix Inc. An active matrix system addresses separately

each pixel of the liquid crystal to give bright, high-contrast images, while the use of plasma as the electronic switches for the liquid crystal pixels results in a relatively simple structure suitable for large liquid crystal screens. The difficulty of switching a large number of large liquid crystals accurately has been one of the main stumbling blocks to large LCD-type flat displays, although small displays suitable for laptop computers have been on the market for a number of years. The cost of the manufacturing process has also been simplified, allowing prices to approach consumer levels.

The PZ-2500 is made in a combined two-piece design that allows the tuner to be removed from the thin-profile body so that television viewers can take full advantage of the flat panel design when positioning it. When the PZ-2500 is connected to other audio and video equipment, the tuner can be connected to the other equipment, and the monitor placed separately.

To go with the flat-panel tv, a new flat speaker system with 1.3 litre volume has been developed, using neodymium speakers and a ribbon speaker to produce a good dynamic range.

At the time of writing it is not known when Plasmatron designs will come to Europe, but this new display design takes television one step nearer to the hang-on-the-wall vid-screens seen in sci-fi movies.

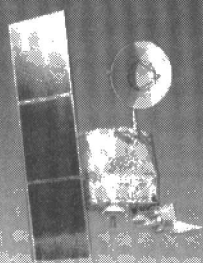


Figure 1 Artist's impression of future vehicles of the next phase of NASA's Mars exploration - the Mars Surveyor '98 missions will include an orbiter and a lander spacecraft currently also being built by Lockheed Martin (Courtesy Lockheed Martin)

Return to Mars



In the next few years, landing on Mars will begin again in earnest, with new, advanced photographic and sampling machinery. Traces of life would be the ultimate prize, but there is much else to know about the Red Planet, says Douglas Clarkson

In an age of scientific advancement where science also strives to be increasingly relevant to the public, the intense interest in the analysis of meteorites from Mars will ensure that for the next ten years or so Mars will remain the focus of scientific investigation. Forthcoming missions include NASA's Mars Pathfinder mission and the Mars Global Surveyor mission. Unfortunately the Mars-96 mission co-ordinated by Russia failed in November 1996, with the loss of a number of experiments. The interest in Mars, however, has a longer term component. Landers are planned for launch in 1998, 2001, 2003 and 2005, and with additional orbiters planned for 1998 and 2003.

Figure 1 indicates an artist's impression of future vehicles for the next phase of NASA's Mars exploration. The Mars Surveyor '98 missions will include an orbiter and a lander spacecraft currently being built by Lockheed Martin. These craft will be launched at the next period of close encounter by Mars and the Earth. There are, however, very real expectations that Mars could contain a host of secrets that may in time lead for the revision of much of our existing scientific understanding. Mars is therefore very much the new frontier of science.

After decades of scientific scepticism regarding the possibility of life within light-years of Earth, the prospect of finding traces of life the solar system - in our own backyard - would radically alter assessments of the distribution of life in the universe. Conversely, in order to prevent contamination of Mars by earth micro-organisms, lander experiments by the USA and Russia are prepared in line with strict quarantine conditions specified by international agreements. The surface conditions on Mars are, however, relatively extreme, the most damaging component being the high levels of ultra violet radiation.

The myths

Mars has tended to capture our imagination. The American astronomer Percival Lowell in 1900 interpreted changes on the planet surface with the time of the Martian year as evidence of water coursing along artificially dug channels to irrigate the arid planet. This view was met with considerable fascination among the public. Also, around this time Nikola Tesla in his Colorado Springs experiments claimed that the source of some of puzzling signals that his magnifying transmitter system was detecting was intelligence on Mars. Scores of science fiction writers have used Mars as a convenient backdrop for diverse fantasies. More recently, the so called 'face on Mars', as captured in NASA frame 35A72 from the Viking missions, has enhanced expectation that more detailed mapping of the Martian Surface in the future might reveal details of a lost civilisation. NASA intends to distribute data on this region on the Internet as soon as it is scanned at high resolution.

From what ever source, there appears locked at some level in the modern psyche (or 'morphic field', as attributed to Dr. Sheldrake), an anticipation that indeed Mars could have supported an ancient advanced civilisation which, for whatever reason, - natural cataclysm, climate change or conflict - faltered.

The reality

There are many similarities between Earth and Mars in the nature of its modes of rotation on its axis. The axis is inclined to the vertical at 25 degrees compared with 23.5 of Earth, and as a result gives rise to clear seasons within the 687 'Earth day' Martian year. The Martian day or 'sol' is some 37 minutes longer than an Earth day. Mars is a relatively small world

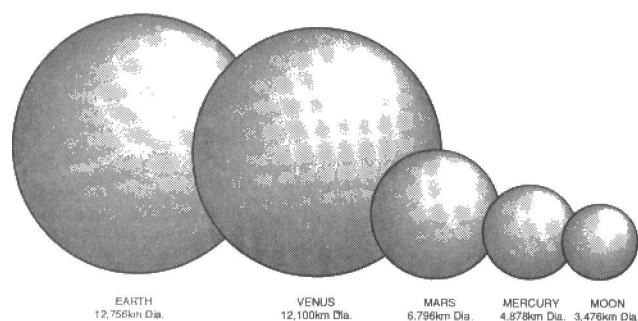


Figure 2 Relative size of Mars compared with other 'inner' planets of the Solar System (Courtesy NASA)

compared with both Earth and Venus (figure 2) with an equatorial radius of 3397 km compared with the Earth's value of 6378 km. Its gravity at the planet's surface is 3.72 m/s² or 38% of that at the Earth's surface. This is one reason why the Mars atmosphere is considerably thinner than the Earth's.

Space mission observations

Table 1 summarises the exploits of exploration so far to the Red planet. Less than 40% of missions have a completely successful outcome.

The first spacecraft to soft-land on Mars was the Soviet Mars-3, although it only returned data for approximately 20 seconds after touchdown, apparently during a dust storm. The Soviet Mars 2 and Mars 3 craft certainly were an ambitious step forward in the exploration of the Red Planet. The first significant data came with NASA's Mariner 9 which was put into a circular orbit in November 1971 until October 1972. It is perhaps relevant that the Mars 2 and Mars 3 probes had been launched towards Mars without detailed knowledge of optimised landing sites on the Martian surface. It was the data

that Mariner 9 sent back that would allow the Viking missions to optimise their chances of safe landings.

The two Viking craft that reached Mars in 1976 provided some answers, but at the same time gave rise to more questions. While the experiments to detect life on the planet gave negative or inconclusive results, images from the orbiters provided clear evidence of vast water flow channels that had been created at a time in the planet's previous long history. Figure 3 indicates clearly what appears to be a tail behind a crater rim as evidence of a huge deluge of water over the area.

Figure 4 shows an interesting image from Viking 1, showing what looks like a familiar desert landscape. The large rock in the foreground is 'Big Joe'. This is a hostile surface, with wide extremes of temperature, very low pressure and a high levels of dangerous ultra violet radiation.

Figure 5 shows the view from Viking II station. The slight slope of the horizon indicates that the craft did not land completely level. The rocks at this site seem to be of a more uniform size distribution than at the site of Viking 1. Both the landers, however, seemed to have luck on their side in the choice of landing site. Perhaps the planned Mars Global Surveyor will discover what became of the early Soviet Mars-3 and Mars-2 landers.

The Martian surface certainly contains some major features. Figure 6 indicates a section of the so called Valleea Marineris which is a major feature extending for around 4000 km along the Martian surface. It is associated with geological faults rather than with erosion mechanisms like wind or water. In places, canyons may be 200 km wide and 7 km deep. The surface of Mars is generally revealed to be one of surprising diversity and one that will no doubt in time provide a great wealth of scientific information.

While the Viking images provided information about the daily changes about a static point on the planet surface, the micro-rover of the forthcoming Pathfinder mission will scout around the landing platform on a series of daily adventures into the Martian outback.

Table 1: Summary of main space probes to Mars

Craft	Origin	Launch Year	Type	Outcome
Mars 1	USSR	1962	fly by	Partial - instruments failed;no data
Mariner 3	USA	1964	fly by	Satellite shroud did not detach
Mariner 4	USA	1964	fly by	Successfully returned 21 photos
Mariner 6	USA	1969	fly by	Successfully returned 75 photos
Mariner 7	USA	1969	fly by	Successfully returned 126 photos
Mariner 8	USA	1971	orbiter	Crashed into Atlantic
Mariner 9	USA	1971	orbiter	Very successful - returned 7329 photos
Mars 2	USSR	1971	lander/ orbiter	? lander crashed Some orbiter data
Mars 3	USSR	1971	lander/ orbiter	Partial: landed in dust storm Some orbiter data
Mars 4	USSR	1973	orbiter	Failed to orbit
Mars 5	USSR	1973	orbiter	Incorrect orbit
Mars 6	USSR	1973	lander	Failed during landing
Mars 7	USSR	1973	lander	Missed planet
Viking1	USA	1975	orbiter/ lander	Successful - together sent 50,000+ photos
Viking2	USA	1975	orbiter/ lander	Successful - together sent 50,000+ photos
Phobos1	USSR	1988	complex	Lost en route to Mars
Phobos2	USSR	1988	complex	Partial - lost near Phobos
Mars Observer	USA	1993	orbiter	Failed at Mars orbit
Mars-96	Russia	1996	orbiter/ lander	Failed - crashed crashed into Pacific



Figure 3: Water outflow channel skirting round crater feature (Courtesy NASA)



Figure 4: Image from Viking 1 showing what appears to be a familiar desert landscape (Courtesy NASA)



Figure 5: View from the Viking II landing site - the distribution of rocks is more uniform compared with Viking 1 (Courtesy NASA)

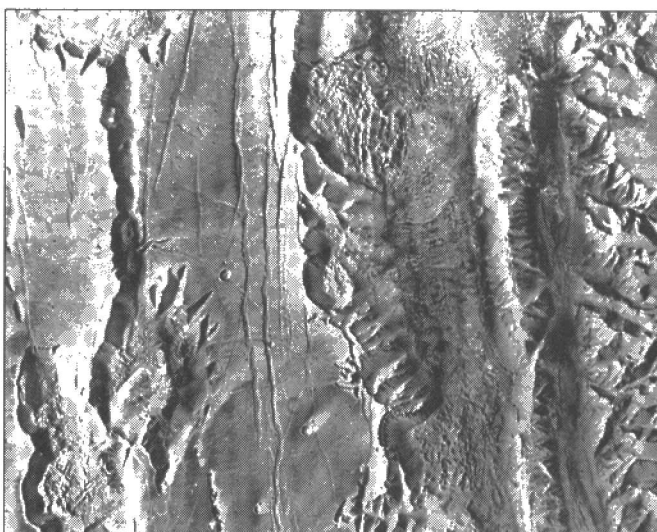


Figure 6: View of the Valles Marineris as obtained by Viking orbiter (Courtesy NASA)

The Martian outback

Why is it that the Australian outback looks so much like the surface of Mars? Anyway, getting back to Mars, periodically high winds in the ultra thin air can raise dust to heights of tens of kilometres. There is therefore a mechanism to redistribute deposits around the planet surface. Such winds tend to be driven by temperature gradients on and above the Mars surface.

The two hemispheres of Mars reflect possibly different periods of planetary history. The southern hemisphere is strewn with craters which were possibly created during one of the earliest phases of the solar system which also left its mark on the moon and Mercury. In the northern hemisphere, more Earth-like features are evident, with large volcanoes such as Olympus Mons and with the existence of what appear to be water outflow channels. One possible source of such 'chaotic terrain' is the melting of subsurface permafrost layers by volcanic activity.

Seasonal dynamics

It is considered that the northern perennial cap is principally composed of water ice, while the perennial southern cap is

composed of frozen carbon dioxide. On Mars the winters in the southern hemisphere are more extensive than those in the north and greater deposits of carbon dioxide become frozen out there from the atmosphere. During winter in the north, the season of summer in the south acts to melt this frozen carbon dioxide into the atmosphere resulting in an increase in atmospheric pressure across the entire planet.

Temperatures on Mars range from -133°C to $+27^{\circ}\text{C}$ with a pressure around 0.8 percent of that of Earth. At the Viking 1 lander site in the northern hemisphere, the pressure varied from a minimum of 6.7 mb at the height of the southern winter (northern summer) to 8.8 mb for the maximum at the height of the southern summer (northern winter).

The southern pole stretches as far as 50 degrees South at the height of its winter and is equivalent to 23 cm of carbon dioxide snowfall over the entire polar region. In Spring the cap sublimates at a rate of one degree of latitude every 5 days with the cap breaking up into several stable remnant fragments. During early autumn a layer of cloud termed the 'polar hood' forms in the region of the southern

Table 2: Atmospheric composition of Mars

Atmospheric composition	Percent
Carbon Dioxide	96.5
Molecular Nitrogen	1.8
Argon	1.5
Molecular Oxygen	0.1
Carbon Monoxide	0.05
Water Vapour	0.02
Neon	0.0001
Krypton	0.00003
Xenon	0.00002

pole as carbon dioxide begins to build up again at the pole. The amount of water vapour in the entire Martian atmosphere is relatively small, equivalent to an iceberg of sides only 1.3 km.

Various components, especially water vapour, may be unevenly distributed in the atmosphere. A key to understanding the present processes on Mars and clues to past history lies in further study of the dynamics of the atmosphere of Mars. On the Earth, carbon dioxide is present at around .032 percent by volume, indicating a partial pressure of 0.32 mb at sea level. On Mars, the partial pressure of carbon dioxide is around 9 mb, depending on elevation. Thus the partial pressure of carbon dioxide is around some 28 times greater than that of Earth and, as a greenhouse gas, must be responsible for raising the temperature of the planet above that which would be achieved with a similar partial pressure of, say, nitrogen.

The ratios of isotopic abundances provide indication of the rate of loss of gases from the atmosphere. Studies of processes of ionic interaction in the high Martian atmosphere have indicated that significant amounts of oxygen and nitrogen could have been lost over periods of geological time. Thus a number of experiments on forthcoming missions will be investigating ionic concentrations within Mars's atmosphere to determine processes involved in the creation of the current atmospheric conditions.

Cycles of climate

The current eccentricity of Mars is 0.0934, with closest approach of 206,600,000 km and furthest distance of 249,200,000. In its eccentric orbit, by sweeping out equal areas in equal times, the seasons are of uneven duration as indicated in Table 3.

In terms of variation to the Martian climate, a surprising number of components come into play. The precession of Mars's spin about its own axis (like a wobbling top) is estimated to provide a cycle with a period of 175,000 years. A separate factor due to the precession of the axis of the orbit in space causes the line joining the perihelion and the aphelion to rotate with a cycle of 72,000 years. The net

Table 3: Length of the seasons of Mars

Northern Hemisphere	Southern Hemisphere	Martian Days
Spring	Autumn	194
Summer	Winter	178
Autumn	Spring	143
Winter	Summer	154

result is that the climatic regime of the two hemispheres changes over with a period of 51,000 years. This cycle will in time cause the extensive carbon dioxide pole to build up over the northern hemisphere with its colder winters but short warmer summers - a mirror image of what takes place at present in the southern hemisphere.

There is also a separate variation in the orbital eccentricity. The current value is 0.0934 though it can vary from 0.004 to 0.141 with a short term variation of period of 95,000 years and a long term variation of 2 million years. These considerations are relevant for determining previous phases of Martian climate history and also anticipating future ones.

The two effects can be described, however, as the crossover of the dominant pole between the two hemispheres and the variation in the relative extremes of the seasons as experienced in the two hemispheres. If conversation was ever a problem on Mars, then the topic of the long long range weather forecast would always get it moving again.

ALH84001: The McKay Paper in 'Science'

It was the paper in Science describing the work on the ALH84001 meteorite which heightened awareness of the search for life both past and present on Mars. The paper is in fact available on line on the Internet, though to be fair it is an advantage to have all the illustrations available 'on line' on the printed page.

Meteors such as ALH84001 are described as belonging to the Shergottite-Nakhala-Chassigny or SNC class of meteorites, which are thought to have come to Earth via impact events on Mars; that is, they were thrown clear of Mars's atmosphere by the impact of a large meteorite arriving from space (rather like a giant game of marbles) and were eventually captured by Earth's gravity. One of the key scientific findings with these SNC meteorites is that the abundance and isotopic compositions of trapped gases in the SNC meteorites has a direct one to one correlation with the levels measured by the Viking landers. It could be argued that nature has been conducting a vast series of sample-return missions between Mars and Earth over a period of many millions of years.

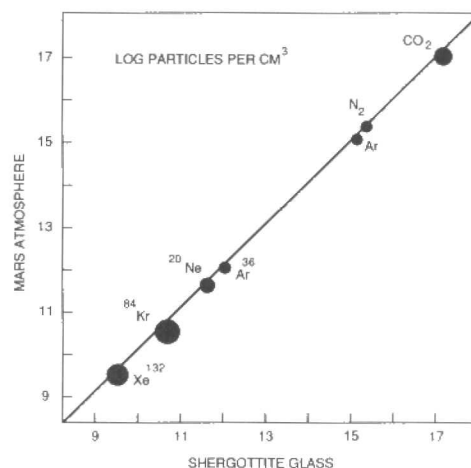


Figure 7 Gas concentration of cavities within Mars meteor Shergotty EET79001 as compared with the Viking atmospheric data (Courtesy NASA)

The gas concentration of Mars meteorite Shergottite EET79001 as compared with the Viking atmospheric data is indicated in figure 7. The fit is unmistakable. This implies that gas cavities in meteors tend to preserve the original atmospheric concentrations from their point of origin. It is not clear, however, how long ago the gas concentrations were established within such material. Also, to escape from the surface of Mars, an escape velocity of 5.4 km/s would be required. To date all the Mars meteorites which have been identified are examples of igneous rocks that would be able to withstand a violent impact. It is likely that sedimentary rocks on Mars would not be able to withstand such violent forces. Thus, the more interesting rocks from the point of view of fossil remains would be unlikely to reach Earth through impact events. Future lander/recovery missions will have to go and find them and bring them back to Earth.

The ALH84001 meteorite is apparently a recent arrival on earth, estimated to have arrived here only some 13,000 years ago. It is likely, however that it actually crystallised 4.5 billion years ago. One shock event on the sample is estimated to have taken place at 4.0 billion years ago, while the formation of the carbonate globules is estimated to have occurred some 3.6 million years ago. The stable isotope data of the carbonate compounds suggest that this material was formed in the temperature range between 0 C and 80 C. It is this temperature range which is at present a topic of international scientific debate. The original specimen weighed 1.9 kg.

It is estimated on the basis of cosmic ray exposure data that the rock was in space as a meteor for about 16 million years. The fact that in general amino acids are found undegraded in such stony meteorites implies that the temperature of their interior was probably not raised above 100 C to 120 C as it fell to earth.

The analysis of ALH84001 seeks to interpret possible traces of life on Mars by comparison with known mechanisms on Earth. While this approach is entirely justified, it also leaves open the possibility that remnants of life on Mars may exist in a form that is currently unknown to us and hence unrecognised.

The key findings with this meteorite were that on fresh fracture surfaces abundant polycyclic aromatic hydrocarbons (PAHs) - often formed in association with biogenic activity on Earth - were identified and that selected carbonate globules resembled those known to have been the result of bacterially induced carbonate precipitates on earth. Also, the PAHs were found in association with the regions rich in carbonates and included pyrene, chrysene and benzopyrene.

The ALH84001 meteorite does not appear to have been significantly weathered by its relatively short sojourn on earth, though it is somewhat friable and is easily broken along pre-existing fracture planes. Also, the levels of PAHs in both the Greenland and Antarctic ice have been studied with indications of levels estimated at around one part per billion. This evidence makes it highly unlikely that the PAHs were acquired from local contamination. Also, levels of PAHs in the meteorite increase with increasing depth towards the core of material.

One group at the Scripps Institution of Oceanography, however, has claimed that ice from the Allan Hills region of Antarctica is 'loaded' with PAHs and resembles the types found in the meteorite.

The set of PAH compounds are really identified with a very large number of individual compounds. On earth, in compounds such as coal and petroleum, hundreds of thousands of individual compounds can be identified. PAHs have also been identified in other meteors such as CM2 chondrites. The set appearing in ALH84001, however, are possibly a unique fingerprint of a relatively simple set of micro-organisms.

In analysis of carbonate globules, these appear to have formed along pre-existing fracture lines - suggesting that these could have been occupied by water. Extensive analysis has been undertaken of such structures using transmission and scanning electron microscopy.

The sub structure within some of the globules reveals items described as 'small regularly shaped ovoid and elongated forms about 20 to 100 nm in longest dimension'. There is claimed to be a similarity between these structures and that observed in calcite concretions known to have been grown from Pleistocene ground water where the sub structure is associated with involvement of nannobacteria in calcite precipitation. In the interpretation of the ALH84001 meteor, there is therefore a very high dependence on assimilating knowledge from a very wide set of fields of terrestrial science.

There has been much criticism of the scientific conclusions of this paper. It is entirely correct, however, that it has been published for it is really to focus scientific application in this area that the authors have revealed their specific scientific approach and method. Whether they are proved right or wrong, the science of analysis of such material will have been moved forward by great strides.

The British connection

During November 1996 at press conference in London, meteorologists from the Open University and from the Natural History Museum presented findings on their work on the apparently much more recently 'delivered' meteor, EETA 79001. This is considered to have formed 180 million years ago and been chipped off Mars some 600,000 years later (that is, a bit over 179 million years ago). Again, the balance of evidence is that this meteorite carries traces of biogenic activity.

A previous paper on the same meteorite had in fact been published in 1989, with the chief researcher, Colin Pillinger of the Open University, at the time explicitly stating that their findings supported the view that life could once have existed on Mars.

The exopaleontology of Mars

Scientists are now planning the best way to direct future unmanned missions to Mars. The two main goals are the study of any fossil record of the planet (exopaleontology) and the search for current life. If, as seems possible, life was once widespread on Mars, coupled with the fact that the crustal activity of Mars seems to very much less than that of the earth, then the chance of discovering fossil remains is relatively high.

There is at present considerable similarity between the earth's pre-Cambrian paleontology and that of the older rocks of Mars. On earth the fossil record is precariously preserved, with around 99% of all species vanishing without trace. With its apparent lack of plate tectonics, any fossil record is more likely to be better preserved on Mars. Mars appears to have a single static crustal layer while on earth

the surface plates float on a denser layer of magma. On Mars, there will be key interest in identifying such geological structures initially by means of mapping processes such as with the Mars Global Surveyor.

The theories of the cycles of Martian climate through geological time are still evolving. A dominant theory is that the surface hydrocarbon cycle involving water on Mars ended in the relatively remote past - at least hundreds of millions of years ago. The evidence of the remnants of this phase could remain in paleo-lake basins - depressions on the surface of Mars. While on Earth, for example, in Antarctica, ice may persist for hundreds of thousands of years, the rapidly changing seasonal dynamics on Mars are unlikely to allow ice or water ice to exist for sufficiently long periods of time to act as a preserving agent for life forms.

Thus the scientific investigations of Mars are designed to answer some very demanding answers and ones which will in turn allow future scientific missions to investigate carefully selected regions of promising geology.

Within NASA's planned 10 year program of Mars exploration, the 2005 Sample Return mission is seen as a key mission for returning samples to Earth. It will be the role of current and future orbiters to provide high resolution mapping information to identify any possible landing sites for such a sample return mission.

The key to determining such surface geology would be with a high resolution thermal emission spectrometer. Calculations indicate that one at a resolution of 100 m/pixel in the wavelength range 1 to 5 microns and with 10 to 20 nm bandwidths (1 micron = 1000 nanometre) would provide useful data to selected future landed missions. This technology, however, is one which is highly developed already for terrestrial mineral survey. One means of obtaining the high spatial resolution in the near infra-red band is to use a balloon mission where the reduced altitude of flight would allow the required level of resolution to be achieved.

Also, it is anticipated that future developments from Pathfinder will employ longer ranging rovers to specific geological targets to obtain mineralogical and organic analysis. It is argued that the 2003 rover mission should be capable of a traverse of several kilometres.

Bearing in mind the likely diversity of Martian geology, the study of the planet will be ongoing. Once the technology of sample return is achieved, this will be followed by further sample return missions.

It goes without saying, however, that the level of interest in meteorites from Mars is now staggering. Sets of meteorites that have been collected for many years are now being exhaustively reviewed. There is, however, the awareness that the discovery of the 'right' rock in the 'right' place could be very much like hunting for a needle in a haystack. It may take numerous sample-return missions to recover relevant specimens.

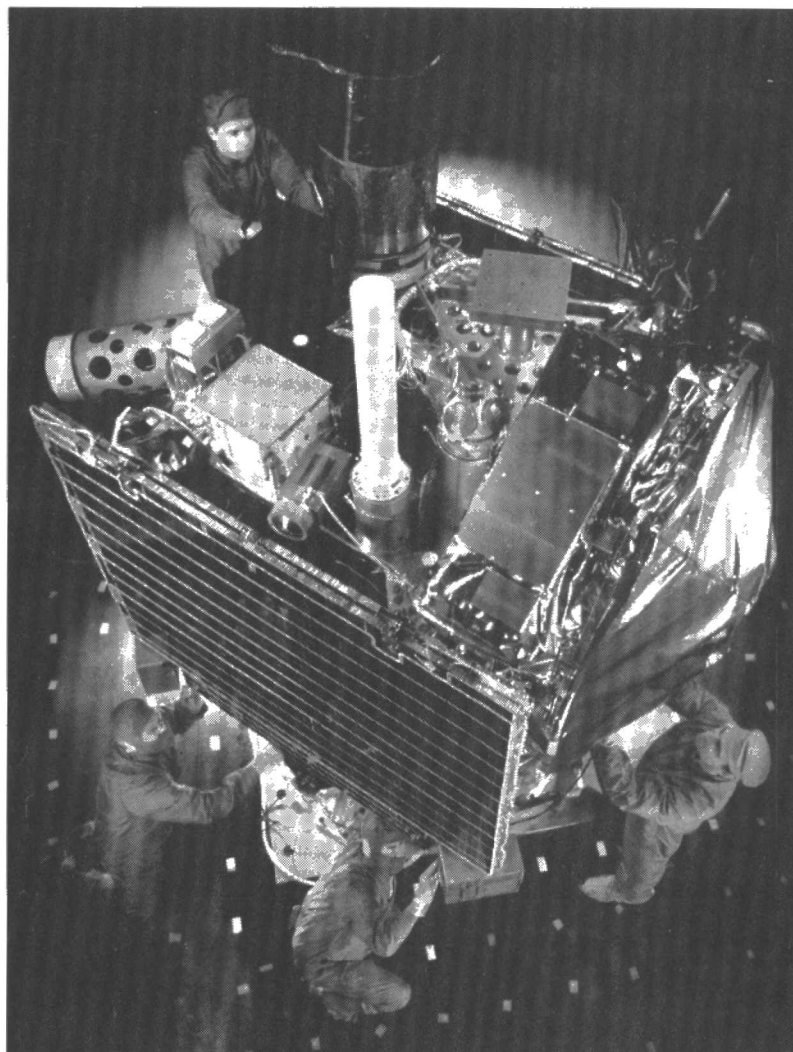
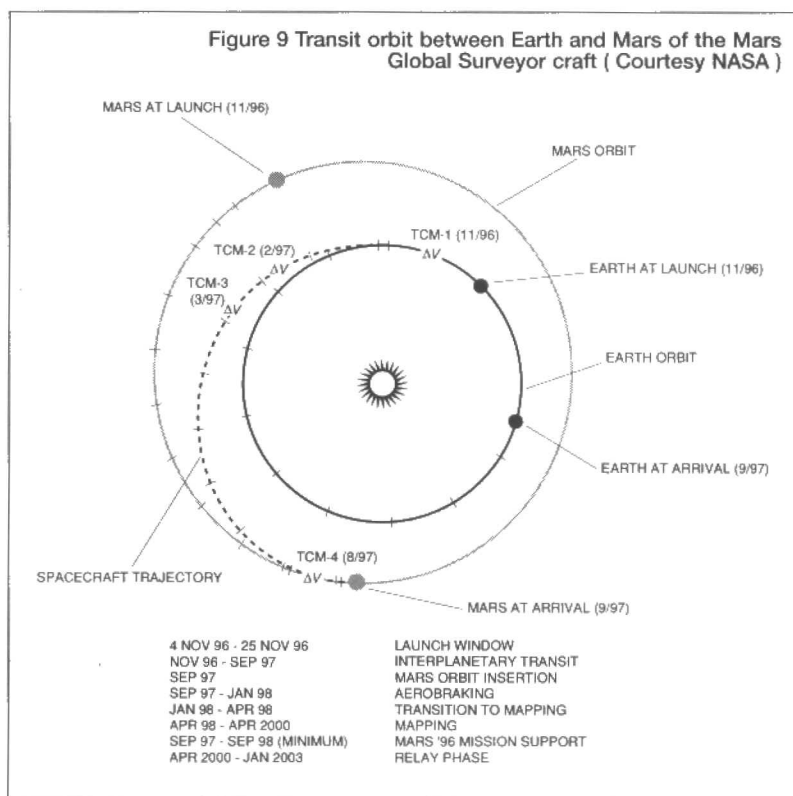


Figure 8 Final preparations on the Mars Global Surveyor as undertaken by Lockheed Martin technicians at the company's facilities near Denver, Colorado (Courtesy Lockheed Martin)



The similarity of soils between the two Viking sites confirms the suspicion that these deposits are part of a globally-distributed homogeneous material. The penetrator experiments which had been planned for Mars-96 sought to analyse samples from more stable layers which would possibly reflect more local geological characteristics. A significant part of the scientific resources of the exobiology and exopaleontology for Mars is to be found within the Ames Space Science Division of NASA.

The Mars Surveyor program

The recent heightened interest in the Red Planet comes in the wake of NASA's Mars Surveyor Program which over the next ten years will launch a series of probes every 25 months to Mars. With a wider international scenario involved, NASA's programme is figuring prominently in the USA's educational science initiatives in a bid to awaken the interest of young people in the mysteries of another planet.

The Mars Global Surveyor

This mission will hopefully allow a detailed high resolution mapping of the Martian surface to be undertaken. Successfully launched in November 1996 on a McDonald Douglas Delta 7925 launch vehicle, the craft should initially pass into an elliptical, near-polar orbit which will

subsequently be altered by mission control staff into a near-circular one some 378 km above the surface. This mission essentially fills the gap of the Mars Observer mission which failed in August 1993 as the craft was about to enter Mars orbit. Mapping processes are planned to last at least two years.

Figure 8 shows final preparations on the Mars Global surveyor as undertaken by Lockheed Martin technicians at the company's facilities near Denver, Colorado. Figure 9 indicates the transit orbit between Earth and Mars of the Mars Global Surveyor craft. After leaving Earth's gravity, the craft has a component of velocity directly towards Mars and one parallel to the orbit of Mars. Because the Earth rotates round the sun faster than Mars, at around 29.7 km/sec compared to mean value of Mars of 24.1 km/sec, the spacecraft is in part using the orbital speed of the Earth to catch up with Mars. The critical manoeuvre at Mars orbit will be the Mars orbit insertion, where the craft's 600 N engine will fire for around 25 minutes to slow the craft down by around 1 km/sec.

The Mars Global surveyor craft has four main configurations of launch (solar panels folded back), cruise, aerobrake and mapping with in the latter three configurations the solar panels aligned at appropriate orientation to the main craft body. Figure 10 shows the Mars Global Surveyor in mapping configuration.

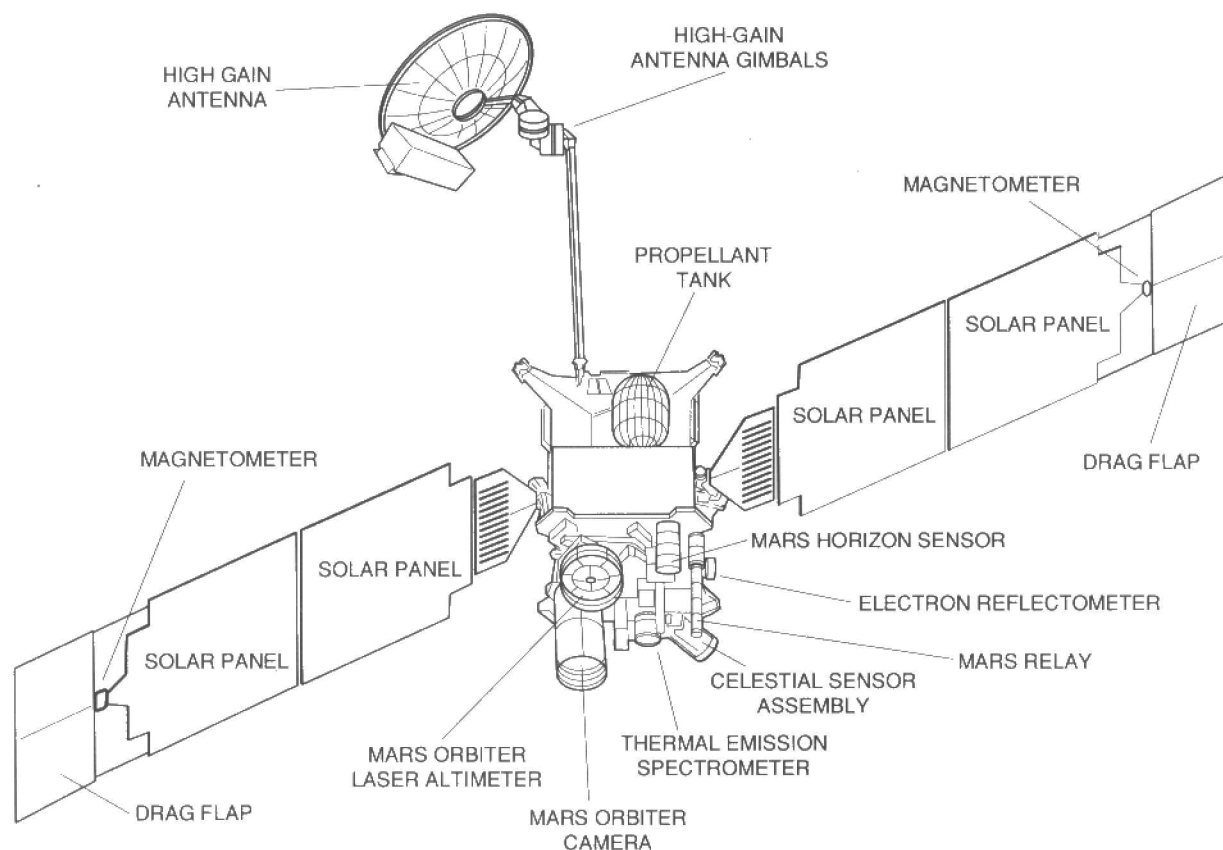


Figure 10 Diagram of Mars Global Surveyor shown in mapping configuration (Courtesy NASA)

Table 4: Key parameters of the Mars Global Surveyor craft

Spacecraft bus	595 kg
Fuel	380 kg
Science payload	75 kg
Cross section area	1.5 m x 1.5 m x height 3 m
Solar panel width	12 m
Solar panel power	980 W (nominal)

The flight to Mars, capture in orbit and alteration of initial elliptical orbit to one with circular geometry for the Global surveyor is a highly complex process. Orbital times will be progressively reduced using aerobraking in the thin Martian atmosphere from an initial capture orbit time of 48 hours to a final orbit of two hours over a period of 130 earth days.

Basic design components

Solar arrays of both silicon and gallium arsenide will provide 667 W of power (at aphelion) for system operation with provision of two nickel hydrogen batteries each of 20 amp-hour capacity for operation while on the dark side of Mars. A series of four 0.75 Gb solid state recorders initially developed for the Clementine mission will be used to save mass.

Extremes of temperature likely to be experienced by electronic subsystems in the space environment are managed by a combination of passive multilayer insulation and active electrical heaters. Encouragingly, while it is stated that much of the support 'frame' systems of Mars Global Surveyor is derived from the Mars Observer Mission, design changes have also been made in the light of the Review Board findings into the loss of the mission.

For the craft launched towards Mars, the main engine will be powered using hydrazine and nitrogen tetroxide giving 596 N thrust and hydrazine only for the series of 12 thrusters each delivering 4.45 N of thrust.

Mars Orbiter Camera (MOC)

The Mars Orbiter Camera (MOC) allows for wide angle stereo scanning of the Martian surface ranging from 140 to 0.4 degrees field of view by means of separate optics and optical CCD detector systems. This translates to image resolutions ranging from 7.5 km/pixel to 1.4 m/pixel. At highest resolution, this is around 35 times better resolution than that attained by the Viking Orbiters.

This range of imaging capability can be used to monitor meteorological and related surfaces at moderate resolution while using extremely high spatial resolution to determine features of specific surface and geological interest such as the 'face' on Mars.

A major part of the value of this imaging role will be to identify and monitor changing features on Mars which will typically be linked to meteorological changes in the atmosphere and the rhythmic changes taking place in the polar regions.

The Mars Global Surveyor mission will provide the detailed information of the surface terrain that will be necessary to plan future robot type missions and possibly in the more distant future any manned missions. As sign of the cost conscious times, a large part of the electronics of the Mars Surveyor Mission are spare parts left over from the Mars Observer mission.

Magnetometer and electron reflectometer

Two triaxial fluxgate magnetometers will measure the magnetic field of Mars in the range from 16 nT to 65,626 nT over seven measurement scales with each having 12 bit measurement resolution. The electron reflectometer will be used to measure energy of electrons which will in turn shed light on the interaction of the solar wind with Mars's weak magnetic field.

Mars Orbiter laser altimeter

This device will measure heights above the Martian surface by measuring the time of flight of laser pulses reflected off the Martian surface by a diode pumped, Q-switched Nd:YAG laser. At a set height of 378 km, the corresponding delay time would be 2.52 ms. Two levels of resolution are implemented of 0.2 degree by 0.2 degree topographic grid with vertical accuracy of 30 m and a higher level of baseline 100 km at a vertical resolution of 2 metres. At this higher level of resolution, the difference in time of flight of signals corresponds to 13 ns.

In addition, the data of signal strength returned as part of the scanning process will also provide data relating to surface reflectivity of Mars at the 1.06 micron wavelength. This in turn can be used to determine details of surface mineralogy and also variation of extent of polar caps.

Mars Relay (MR)

The Mars Relay, which is a French designed module, will relay data from lander packages placed by future Mars missions. This therefore will provide for significant economies of scale in the design of such lander missions. Data will be transmitted to stations at 437.1 MHz (at 1.3 W) and received from stations at 401.5 MHz and 405.6 MHz.

Thermal Emission Spectrometer (TES)

While the surface of Mars is much colder than that of earth, there is considerable variation with surface co-ordinates and also on time scales of hours, days, weeks, months and years. At the heart of the TES is a Michelson Interferometer covering the range 6.25 to 50 microns.

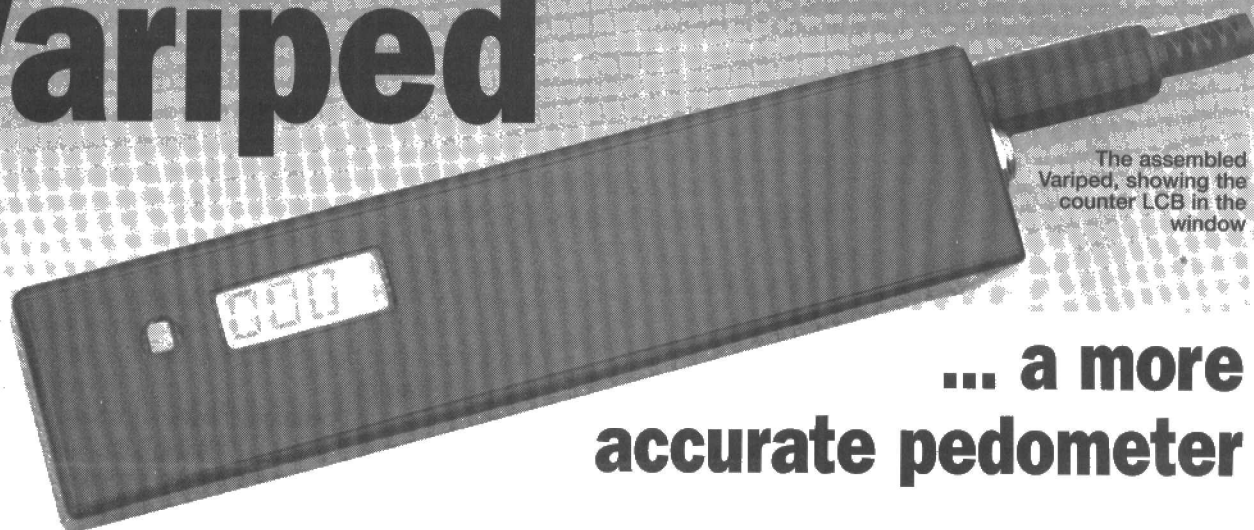
This module will allow location and temperature measurement of water ice and carbon dioxide condensate clouds. It will also be possible to monitor the growth and retreat of the polar cap deposits. Measurement at selective wavelengths will also allow monitoring of atmospheric temperature, pressure, water vapour and ozone profiles.

Current status

A trajectory correction manoeuvre was successfully undertaken on the 21st November. On the following day a latch valve was closed to shut off flow of high pressure helium to Surveyor's propellant tanks. This was undertaken to prevent over-pressure condition occurring. Also, a valve has been closed to prevent nitrogen tetroxide from damaging a check valve in the line between the nitrogen tetroxide and the helium tank. The next series of trajectory correction manoeuvres will be undertaken using the existing residual pressure in the propellant tanks. The next sequence will be to activate the science experiments and monitor their function. The Mars Orbiter Camera and Thermal Emission Spectrometer will image the earth for calibration purposes. So far so good.

NEXT MONTH in the second part of *Return to Mars*, Douglas Clarkson looks at the successful Mars Pathfinder mission and the tragic loss of the Mars-96 project.

Variped



... a more accurate pedometer

Countryside strider Mike Rhodes built his made-to-measure distance counter using a low-cost standard pedometer and an EPROM programmer.

The calibration of a standard pedometer is based on a nominal stride length for the user, but it has been established that the stride length of an individual is not constant. It can, however, be closely predicted from the walking speed.

By collecting personal data that relates stride length to stride duration, and loading this information into a memory, it is possible to design a pedometer - the "Variped" - which uses the information to achieve an accuracy that is in a different class when compared to a standard device.

Project beginnings

This project grew out of my requirement for a really reliable pedometer which could be used to keep a check on my "keep fit" program, and also help with route-finding when out walking. Finding the start of an elusive footpath, for example, could be made easier by knowing the exact distance from the last landmark.

Whereas the basic pedometer normally counts steps or strides, advanced models often include an extra function to measure distance. I discovered that this second function gave less reliable results, because it depends for its operation on a single measurement for the user's stride length, which is subsequently used to increment the total

distance travelled by each stride taken. But stride length varies with speed, so unless one walks at a rigidly defined speed, the measurement will not be a true one.

However, when measurements of stride lengths for a series of given walking speeds were carefully recorded, they were found to vary in a predictable way. It seems that, as one walks faster, more energy is directed into driving the feet and legs forwards, which in turn produces a longer stride length.

Over the normal range of walking speeds, a graph of stride length plotted against walking speed showed that a given increment of walking speed gave a proportional increase in stride length (see figure 1).

This proportional relationship may not be universal, but by collecting the appropriate data, the variation in stride length with walking speed - or, put another way, the variation in stride length with stride duration (that is, the time taken for one stride) - can be determined. Plotting a graph of stride length against stride duration (figure 2) enables the current instantaneous stride length to be predicted. By this method, I found that stride length was repeatedly predictable to within 2 or 3 per cent, whereas over the test range of from 2 to 5 miles per hour, actual stride length varied by something approaching plus or minus 20 per cent.

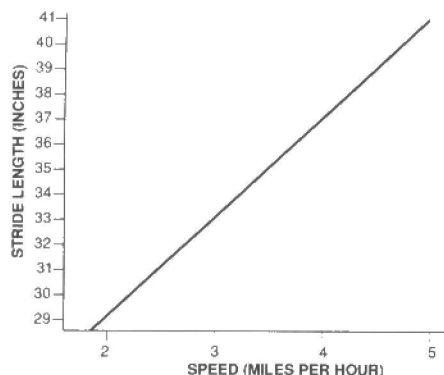


Figure 1: The smoothed graph of Variped stride length vs. speed for the author.

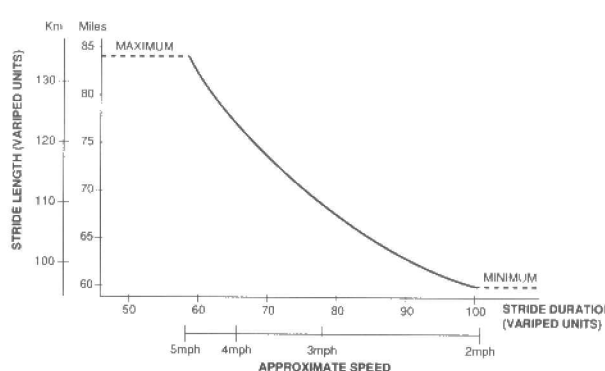
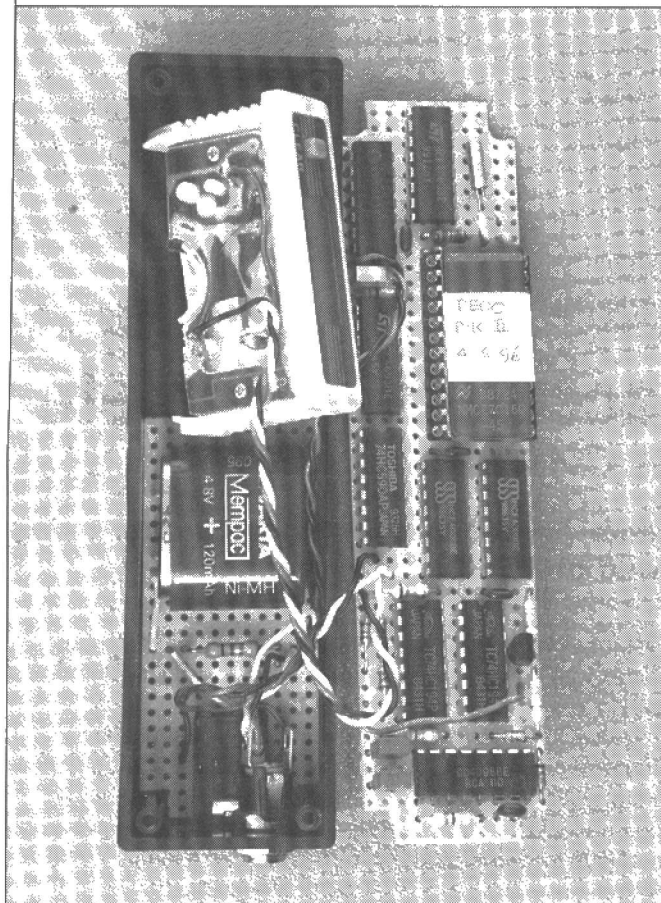


Figure 2: The smoothed graph of Variped stride length and stride duration in "Variped" units.

The Variped showing the counter unit, here cannibalised from a low-cost standard pedometer, being mounted in the box.



Personal Data

To obtain accurate data on stride length and duration, I used the following method:

A quarter-mile section of local road, fairly straight and level, was selected, and landmarks were chosen at the start and finish of the section by consulting the "25 inch to 1 mile" (1/2500 scale) Ordnance map at the local library. Constant walking speed over the quarter-mile section was maintained by using a small electronic metronome in my top pocket, keeping my strides at a constant rate for the purpose of data-gathering. The overall time was measured using a wrist stop-watch. Using the metronome reading, the stop-watch time and the quarter-mile distance, the stride length and stride duration were calculated for several different walking speeds. (See figure 3.)

Principle of the Variped

Having plotted some reliable data, I now incorporated this into the design of an accurate pedometer. The requirement was for a device which adds up stride lengths - not standard stride lengths, but variable stride lengths calculated from stride duration. A table (figure 4) relating to these two variables can

APPROX. WALKING SPEED mph	COLLECTED DATA		STRIKE DURATION v-p units f = 128Hz	STRIKE LENGTH	
	METRONOME beats/min	TIME secs		v-p units Miles	Km
2	72	459	106.7	51.8	93.5
	84	360	91.4	63.5	102.2
3	96	299	80.0	66.9	107.6
	104	268	73.8	68.9	110.9
4	112	226	68.6	75.9	122.0
	120	203	64.0	78.8	126.8
	128	187	61.0	81.5	131.1
5	132	176	58.2	82.6	133.0

Figure 3: the data collection table compiled for the author

be derived from a smoothed graph plot and loaded into an eprom. The Variped measures the time taken for each stride, and accesses the eprom to determine the length of that stride. Successive stride lengths are then added into an accumulator register to give a record of the total distance travelled.

The design of the Variped is outlined in the block diagram (figure 5). The distance covered is displayed on a proprietary four-digit decimal counter; the input to the counter is pulsed once every thousandth of a mile, so that the maximum reading is 9.999 miles.

Various dedicated counters are available but, for economy, I actually used the one which came as part of my inexpensive basic pedometer, bought for around a fiver. Not all of the pedometer was required for the display, so I removed the battery, and cut the pedometer case and the printed circuit to fit into the selected black plastic box. Wires were then connected to the power supplies and switch input which was previously connected to the vibration detection mechanism in the shop-bought pedometer. A small decoupling capacitor across the power supplies is advantageous.

Accumulator register

The input pulse to the display counter is derived from an 8-bit (accumulator) register which holds a running total of the increments in distance for each stride coming from the eprom table. When the most significant digit of this register is incremented, and changes from 0 to 1 or vice versa, the change is detected and a pulse generated by a monostable circuit. Because the pulses must occur at intervals of one thousandth of a mile, the number loaded into the eprom must be suitably scaled; firstly, the number must not exceed the 7-bit maximum of 127, so that each change of the most significant bit can be detected, and secondly, the number 128 must correspond to a distance of 1 thousandth of a mile for a correct readout.

Since 1 mile = 63360 inches, the number loaded to the eprom will = $128 / 63.36 \times (\text{stride length in inches})$.

The "Variped distance unit" is defined as that distance travelled for an increase of one unit in the accumulator register.

Therefore, where the output pulses occur at intervals of 1/1000th of a mile, then:

$$128 \text{ Variped distance units} = 1/1000 \text{ mile.}$$

If a metric result is required, then output pulses would be arranged to occur at 1/1000th kilometre intervals, that is, every metre, and then:

$$128 \text{ Variped distance units} = 1 \text{ metre.}$$

The metric measurement highlights the problem that one stride may well be longer than 128 Variped distance units (1 metre). To overcome this, the spare data bit of the eprom output is used to generate a clock pulse for the accumulator register, so that half the maximum stride length may be added shortly after the initial stride switch input has been received. This means that the variable part of the distance loaded into the eprom is reduced to less than half of its original value.

My walking stick

Incidentally, most of my testing was carried out using an adapted collapsible walking stick (which, swung in the normal manner of walking sticks, one tap per two steps, measures double stride lengths), so the above solution is used in this

version also. As the walking stick is conveniently hollow, I was able to fit into it a spring-loaded piston cannibalised from an old solder-sucker, set to operate a simple On/Off switch and thus record each stride impact and feed it to the counter, which was taped to the outside of the walking stick (see photograph). Of course, there are many ways of registering stride impacts, including using a standard pedometer, or part of it, as the input device.

The circuit

The Variped circuit (figure 6) and contains 10 integrated circuits to time the stride, access the eeprom, and drive the display counter. Crystal oscillator and counter IC1 generates suitable timing clocks for measuring stride length. A further counter 1C3 of eight bits is used to access the stride length data in the eeprom so that a maximum of 256 locations may be used.

For single stride operation, counter output IC1 pin 14 is used to give increments of 1/128th of a second and a maximum time of two seconds per stride. For the walking stick version, output IC1 pin 13 is used, giving increments of 1/64th of a second and a maximum double stride time of four seconds.

The 8-bit counter 1C3 is started by the reset derived from the pedometer switch input routed via a debounce circuit, and two "D" type stats (IC2) which synchronise it to the timing clock. The counter runs until it reaches its maximum count (255), when the carry input inhibits further clock inputs. If the next stride input has not occurred by the time the counter stops, then the stride length given by the eeprom (IC4) is arranged to stay at a minimum value, awaiting the next input.

The least significant seven bits of the eeprom data outputs are used to increment the total distance. These outputs are taken via a parallel adder (IC6 and IC7) to the accumulator register (IC8 and IC9). If required, the most significant eeprom data bit can be used to add part of the stride length as previously described. This bit is normally zero but pre-loaded with a "one" for the address corresponding to approximately half the minimum stride duration; for example, if the stride durations loaded run from 0.9 second to 2 seconds, then the "one" bit is loaded for the time of about 0.45 second. See figure 7.

The most significant bit of the accumulator register is taken to two monostables (IC10) so that one is triggered by a change from zero and the other by a change from one to zero. The outputs from the two monostables are "ORed" by a single diode gate and then taken to an npn transistor to drive the counter display.

The specified mix of CMOS and High Speed CMOS integrated circuits has been chosen to maintain timing tolerances and should be adhered to, or accuracy will be compromised.

Figure 4: the Variped eeprom table: stride duration and length derived from the smoothed curve.

TIME UNITS		EPROM ADDRESS (Hex)	MILES		KILOMETRES	
Dec.	Hex.		Distance units (Dec)	EPROM DATA (Hex)	Distance units (Dec)	Less offset (Hex)
		0		54		44
		1		54		44
		↓		↓		↓
		1B		54		44
		↓		↓		↓
		1C		54		44
		1D		54		44
		↓		↓		↓
58	3A	38	84	54	136	68
59	3B	39	81	51	130	62
60	3C	3A	78	4E	126	58
↓	↓	↓	↓	↓	↓	↓
100	64	62	60	3C	99	31
101	65	63	59	3B	98	30
↓	↓	↓	↓	↓	↓	↓
102	66	64	58	3A	97	29
		↓	↓	↓	↓	↓
		65	58	3A	97	29
		↓	↓	↓	↓	↓
		FF		3A		1D
		↓		↓		↓
		100 - 1FF	SPARE DATA SET		SPARE DATA SET	
		200 - 2FF	SPARE DATA SET		SPARE DATA SET	
		300 - 3FF	SPARE DATA SET		SPARE DATA SET	
		400 - 7FF	SPARE		SPARE	

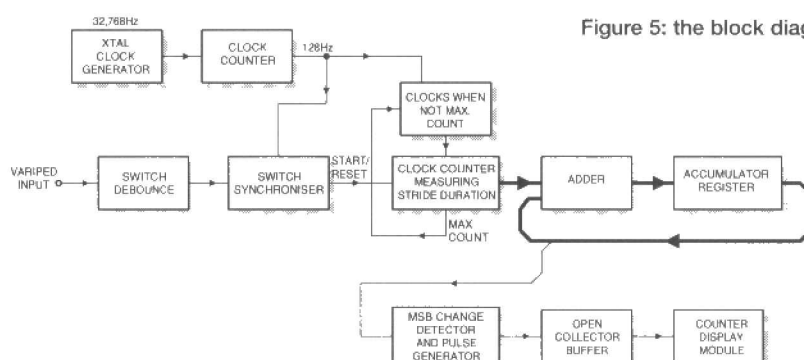


Figure 5: the block diagram.

Assembly

A printed circuit board (figure 6) has been designed to fit into the specified black plastic box. This box will also accommodate the battery and a small counter, or the pedometer counter as described. The choice is yours. Integrated circuits (apart from the eeprom) are soldered directly into the pcb, taking care to solder the through-hole connections on both sides of the board. the eeprom is an exception, and should be mounted in a turned-pin socket.

Only two plugs have been used to connect to the box and are located at the bottom, so that rain is not a problem. These are the 3.5 mm input jack socket with attached switch (arranged so that inserting the jack plug switches on the Variped), and a 2.1 mm power socket for connecting a 12 volt dc supply for charging the battery.

The Variped showing the counter unit and battery board in the box, and the main board wired up. (This prototype was built on stripboard).

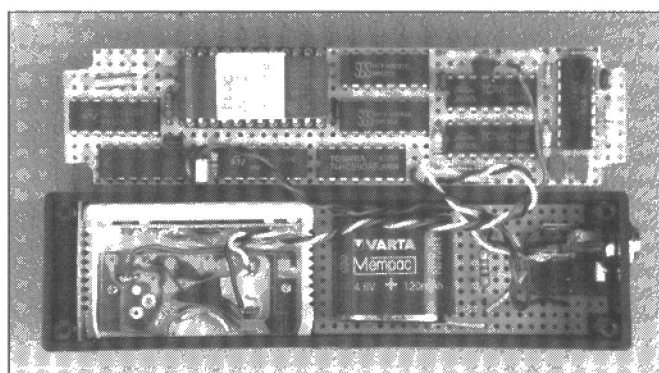
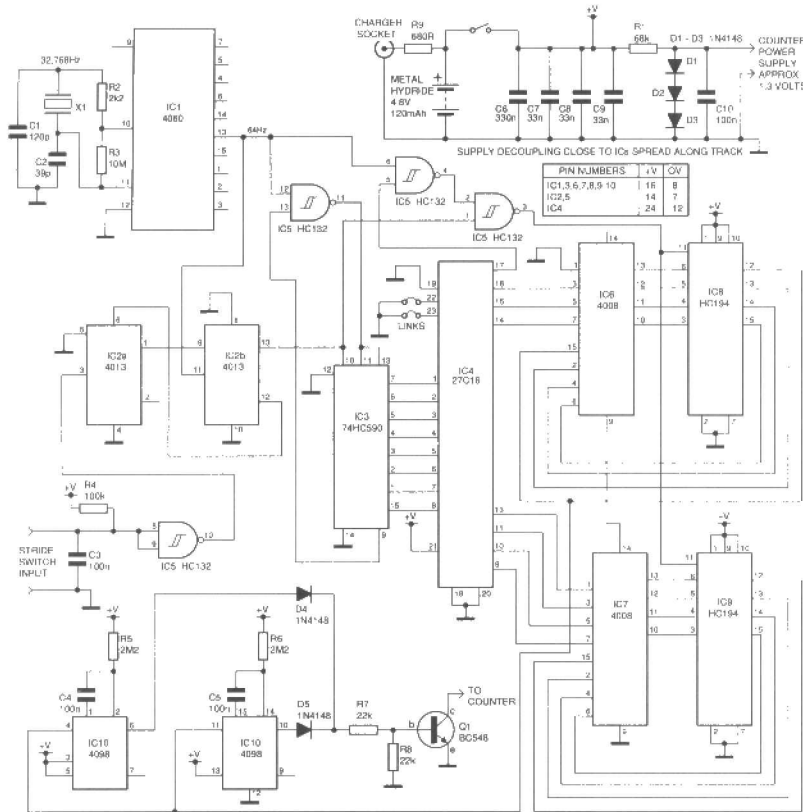


Figure 6: the circuit.



Stride rate (metronome reading) = r beats per minute
Time for a quarter-mile walk = q seconds

Stride duration = $1 / r$ minutes = $60 / r$ seconds = $60 / r \times f$ Variped time units.

Number of strides in a quarter-mile = (time for a quarter-mile / stride duration) = q seconds / $(60 / r)$ seconds = $(r \times q) / 60$.

Stride length = a quarter mile / the number of strides in a quarter mile = $250 / (r \times q / 60) = 15000 / (s \times r \times q)$ Variped distance units.

For single step Variped:
 $f = 128$
 $s = 1 / 128$

Stride duration = $7680 / r$
Stride length = $1920000 / (r \times q)$

For walking stick Variped:
 $f = 64$
 $s = 1 / 128$

The way ahead

Only one-eighth of the eeprom is used to store one set of data; the pcb includes extra pads to simplify the addition of a switch, so that more sets of data may be included. For instance:

- * A set of data for jogging
- * A set for use by a second person
- * Data for readout in kilometres
- * Data for stride count - by loading each location with hex 40 and using offset 40, the readout would show stride count. This is a roundabout way, but would simplify switching.

Note that, if you are using a standard pedometer to detect strides and drive the Variped, it may be necessary to keep the pedometer and the Variped as two separate units, since the extra weight of the Variped may affect the movement of the detector, and therefore its reliability.

Variped parameters

Stride duration clock frequency = f Hz

IC pin	f	increment	max. stride duration
IC1 pin 6	256Hz	3.90625 ms	1 second
IC1 pin 14	128Hz	7.8125 ms	2 seconds
IC1 pin 1	364Hz	15.625 ms	4 seconds

Stride length measurement units (for input to counter of 1/1000th mile) = s thousandths of miles where $s = 1.128$. (1/1000th mile = 63.36 inches; measurement increments = 0.495 inches.)

Data collection parameters (using metronome and quarter-mile test distance) as measured:

Stride duration = $3840 / r$
Double stride duration = $7680 / r$

Stride length = $192000 / (r \times q)$
Double stride length = $384000 / (r \times q)$

Metric parameters

Stride duration clock frequency = f Hz

IC pin	f	increment	max. stride duration
IC1 pin 6	256Hz	3.90625 ms	1 second
IC1 pin 14	128Hz	7.8125 ms	2 seconds
IC1 pin 1	364Hz	15.625 ms	4 seconds

Stride length measurement units (for input to counter of 1 metre) = s metres where $s = 1.128$. (Measurement increments = 7.8125 mm.)

Data collection parameters using the metronome and a half-kilometre test distance:

Stride rate (metronome reading) = r beats per minute
Time for a half-kilometre walk = q seconds

Stride duration = $1 / r$ minutes = $60 / r$ seconds = $60 / r \times f$ Variped time units.

Number of strides in a quarter-mile = (time for a half-kilometre / stride duration) = q seconds / $(60 / r)$ seconds = $(r \times q) / 60$.

Stride length = a half-kilometre / the number of strides in a half-kilometre = $500 / (r \times q / 60) = 30000 / (s \times r \times q)$ Variped distance units.

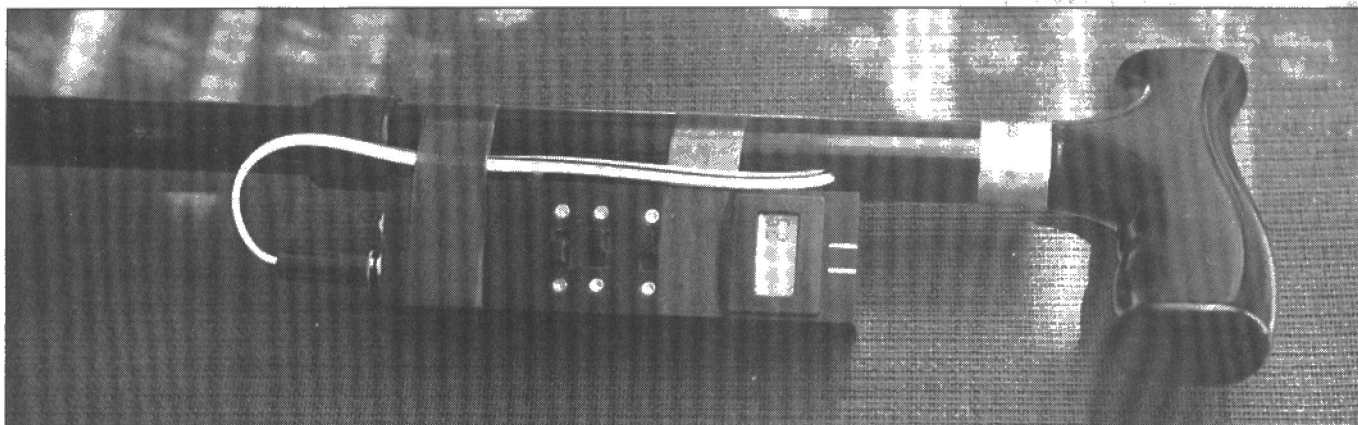
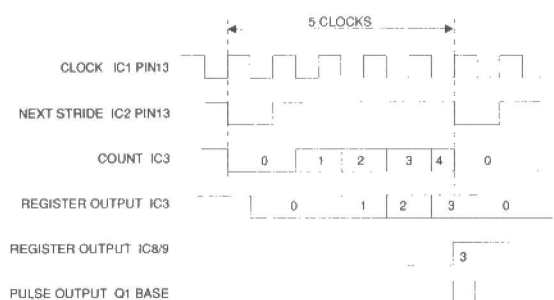
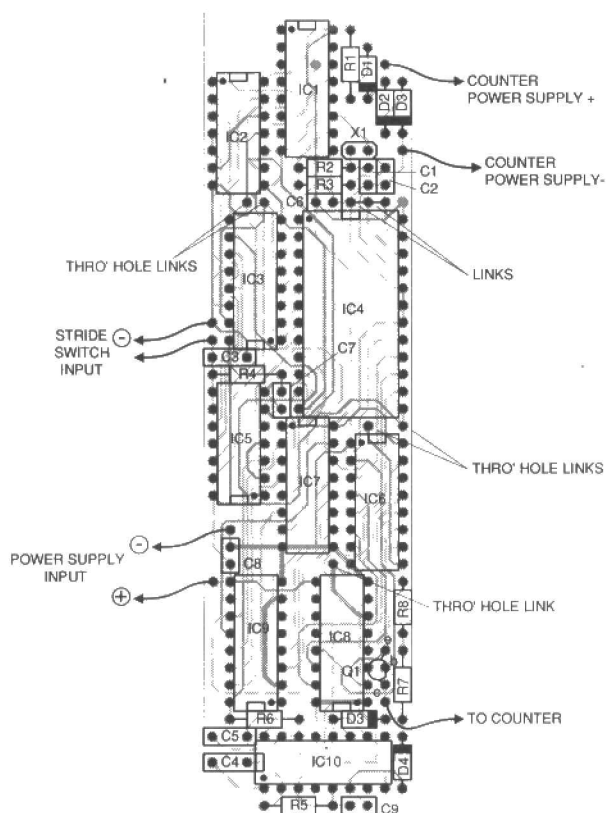


Figure 7: the timing diagram.



2 COUNTS ARE LOST BETWEEN STRIDES
THEREFORE IN EPROM, STRIDE LENGTHS
MUST BE LOCATED IN: ((CORRESPONDING STRIDE DURATION ADDRESS) - 2)

Figure 8: the component layout of the PCB.



Above: The author built strapped his original model to a hollow walking stick into which he had mounted a spring loaded piston (cannibalised from an old solder sucker) to provide a signal at each stride. The walking stick measures double strides. Parts of a low-cost pedometer can be used, wired up to the Variped, to provide the stride input. The remaining part of the cannibalised pedometer provides an alternative counter unit.

PARTS LIST For the Variped

Main Board

Resistors

R1	68k
R2	2k2
R3	10M
R4	100k
R5,R6	2M2
R7,R8	22k

Capacitors

C1	120pF
C2	39pF
C3,C4,C5	100nF
C6,C7,C8,C9	33nF

Semiconductors

IC1	4060
IC2	4013
IC3	HC590
IC4	27C16
IC5	4093
IC6,IC7	4008
IC8,IC9	HC194
IC10	4098
Q1	BC548
D1 - D5	1N4148

X1	Watch crystal 32768 Hz
----	------------------------

The counter

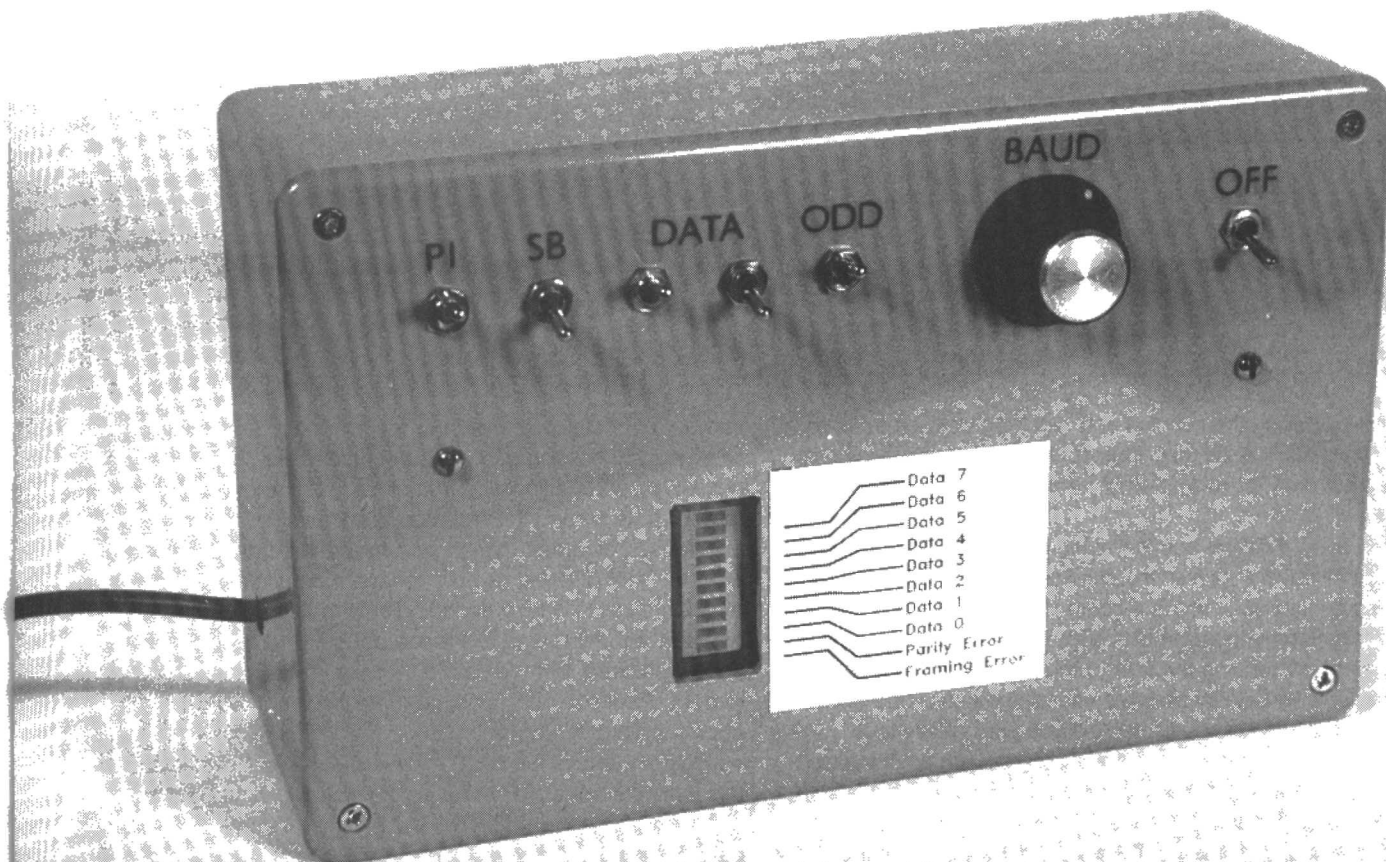
C10	100nF
Counter-pedometer part	(eg Maplin WC35Q)

The battery board

R9	680R (adjust for correct supply to counter)
Nickel-metal-hydride batter	4.8 volts 120 mAh (eg Maplin BN25C)
3.5 mm stereo jack socket with switch	
2.1 mm power socket	

Miscellaneous

Box with internal dimensions 120 x 30 x 25 mm (eg Maplin FT31J), pcb; some Vero board or similar to mount the battery and sockets on.



RS232C Tester

Connecting a printer or other serial peripheral to a computer can be a trying experience. Robert Penfold's RS232C Tester will help to sort out the signals.

Interfacing computers to printers, modems, etc. has a reputation for being a bit awkward. I think it is fair to say that in the early days of computing there were a lot of so-called "standard" ports that did not genuinely conform to any accepted standard. It was often a matter of trying every possible method of interconnection in the hope that one of them would work properly! These days things are generally much better, but serial interfacing via a standard RS232C port can still be tricky. Serial port connectors are now reasonably well standardised, but there are still some nonstandard types (the nine pin PC variety) for example. The main problems seem to be the way in which some systems implement hardware handshaking, together with the numerous baud rates and word formats available.

This tester is designed to be connected in place of the peripheral device, and its purpose is to show whether or not the sending device is actually sending any data, and also to enable a check whether the baud rate and word format are correct. Basically, what the unit does is to decode the incoming serial data and feed the received bytes to an eight LED display which shows the decoded binary patterns. It can obviously be of great help to check the decoded binary values, but there are two further LEDs which are often of equal importance: one of these switches on if there is a framing error, which means that the decoder has not found a valid stop bit. This can occur when the wrong word format is in use, but usually means the sending and receiving baud rates are not matched. The second LED indicates a parity error, and this is obviously only applicable when using a word format that includes parity checking.

An industry standard 6402 UART is used as the decoder, and this can handle practically any word format (one or two stop bits, with five, six, seven, or eight data bits, and with or without either form of parity checking). The crystal controlled clock generator ensures that the receiving baud rates of 1200, 2400, 4800, 9600, and 19200 baud are set with great accuracy. Baud rates below 1200 are little used these days, but the clock oscillator can also provide decoding at 75, 150, 300, and 600 baud if desired.

Serial Formats

A basic half duplex (one way) RS232C serial link is a two-wire system, with one earth wire and one signal type. The bits of data are sent one-by-one along the signal wire, but it is obviously necessary for the receiving device to have some means of identifying each bit correctly. A normal RS232C system is asynchronous, which means that it does not have an additional line that carries some form of synchronisation or clock signal. To some extent the synchronisation problem is

Figure 1: an example serial byte. All word formats have one start bit



handled by having the sending and receiving devices operate at standard clock rates (baud rates). A baud rate of (say) 1200 means that data is transmitted at a rate of 1200 bits per second.

Each byte of data is accompanied by some additional bits which further assist the synchronisation process. There is always one start bit which is sent ahead of the first data bit. This is followed by the data bits, with the least significant bit being sent first, running through to the most significant bit which is sent last. Serial systems use between five and eight data bits, but in a computer context you are unlikely to encounter modern equipment that operates with anything less than full eight bit bytes. After receiving the start bit, the decoder samples the state of the signal line at the appropriate intervals, and assembles the byte of parallel data in a shift register.

The data bits are always followed by additional bits. There are either one or two stop bits, or in the case of five-bit word formats there can sometimes be one and a half stop bits. The purpose of the stop bits is simply to ensure that there is a reasonable gap between one set of bits and the next. Setting the decoder to the wrong number of stop bits will not necessarily result in corrupted data.

Some systems implement a form of error checking called parity checking, but this is quite rare these days. With parity checking in use, the sending device always sends an odd

number of ones, or an even number of ones, depending on whether odd or even parity has been selected. Where necessary, an additional bit (the parity bit) is added between the last data bit and the first stop bit. The receiving device can check each decoded byte to ensure that it contains an odd or even number of ones, as appropriate. If an unsuitable number of bits are set to one, a decoding error has occurred. The problem with this system is that a double glitch can leave the parity unaltered, but the data corrupted. These days some form of checksum testing is the more popular method where error checking is required.

Figure 1 shows the basic make-up of a serial signal, and in this example the word format is one start bit, eight data bits, two stop bits, and odd parity. The binary code contained in the data bits is 01100011. Incidentally, although there may be one or two stop bits, there is always a single start bit.

The 6402 UART

The 6402 UART (universal asynchronous receiver/transmitter) chip is a 40-pin device which has the pinout arrangement shown in figure 2. In this case we are only interested in its ability to decode serial signals, and its transmitter section is therefore left unused. Consequently, many of the pins are left unconnected.

The decoded bytes are placed in the receiver buffer register, and the parallel data is available on RBR0 to RBR7 (pins 5 to 12). The PE and FE outputs at pins 13 and 14 go high if a parity error or a framing error occurs. A clock signal at 16 times the required baud rate is applied to pin 17. The 6402 has facilities to handle handshaking, but in this case the data is effectively processed immediately, and the handshake pins are left unused. The serial input signal is fed to pin 20, but it must be inverted in order to give a signal of the correct polarity for the 6402.

With the control register load input (pin 34) held low, the word format is determined by the five bit binary code placed on pins 35 to 39. Taking pin 35 low enables parity checking, and pin 39 then selects the type of parity checking. Pin 36 is used to select the required number of stop bits, and pins 37 to 38 control the number of data bits. Pin 21 is the master reset input, and this is pulsed high at switch-on to initialise the device correctly.

Circuit operation

The circuit diagram for the RS232C tester appears in figure 3. C5 and R6 provide the reset pulse at switch-on. The eight data outputs and two status outputs drive a ten-LED bargraph display (D1 to D10) via separate current limiting resistors (R7 to R16). The LED current is only about 5 milliamps, but this gives reasonable display brightness. The required word format is selected using S1 to S5. The word format programming inputs of IC2 are normally held low by pull-down resistors R1 to R5, but closing one of the switches takes the appropriate input high.

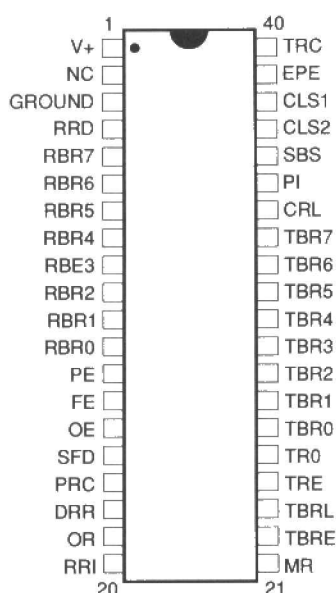


Figure 2: the pin-outs of the 6402 UART

RS232C signals are specified to be between plus and minus 5 volts and plus and minus 30 volts, and not at normal five volt logic levels. The 6402 on the other hand, does operate at normal five volt logic levels. The incoming serial signal must therefore be converted to suitable voltage levels, and this is achieved using one of the buffers in IC1. Although the tester does implement any form of handshaking, the transmitting device may well refuse to transmit any data unless it receives suitable handshake signals. This normally means holding the CTS (clear to send) and DSR (data set ready) lines high. IC1 includes two transmitting buffers, plus a simple switching power supply circuit which generates a plus and minus 10 volt supply for these buffers. In this case the inputs of the buffers (pins 10 and 11) are taken to ground so that the outputs are set permanently high. The +10 volt and 10 volt supplies are available at pins 2 and 6 respectively.

The clock signal is crystal controlled so that the baud rates are set with a very high degree of accuracy. IC3 is a CMOS quad 2 input NOR gate, but in this circuit only two of the gates are utilised. The other two gates have their inputs connected to one or other of the supply lines, but are otherwise ignored. Both gates have their inputs wired together so that they operate as simple inverters. IC3a operates as the crystal oscillator, and IC3b acts as a buffer stage which ensures that an output signal at full CMOS logic levels is provided.

IC4 is a 4040BE 12 stage binary "ripple" counter. The 2.4576MHz output from the oscillator is divided by eight to provide a 307.2kHz clock signal that gives operation at 19200 baud. Further divisions by two provide clock signals for operation at 9600, 4800, 2400, and 1200 baud. If required, the outputs at pins 13, 12, 14, and 15 can be used to provide baud rates of 600, 300, 150, and 75 respectively. S6 selects the required output and couples it to the clock input of IC2. The reset input at pin 11 of IC4 serves no useful purpose in this circuit, and it is simply connected to ground.

The circuit requires a reasonably stable five volt supply, and this is derived from a nine volt battery via monolithic voltage regulator IC5. The current consumption of the circuit varies enormously depending on the number of LEDs switched on, and the settings of the word format switches. It can be anything from a few milliamperes to around 50 milliamperes or so. A PP3 battery is adequate as the power source if the unit will only be used intermittently for relatively short periods. Otherwise a higher capacity battery such as six HP7 size cells in a holder will be required.

Construction

The stripboard layout for the RS232C tester appears in figure 4 (the component side) and figure 5 (the copper side). The board measures 63 holes by 26 copper strips. Once the board has been trimmed to size, drill the two 3.2 millimetre diameter mounting holes and make the breaks in the copper strips. There is a special tool for cutting the copper strips, but a hand held twist drill bit of about 5 millimetres in diameter does the job quite well. Make sure that the strips are cut across their full widths, but try not to cut any deeper into the board than is absolutely necessary, as over zealous cutting can seriously weaken the board.

Figure 3: the circuit for the RS232 tester

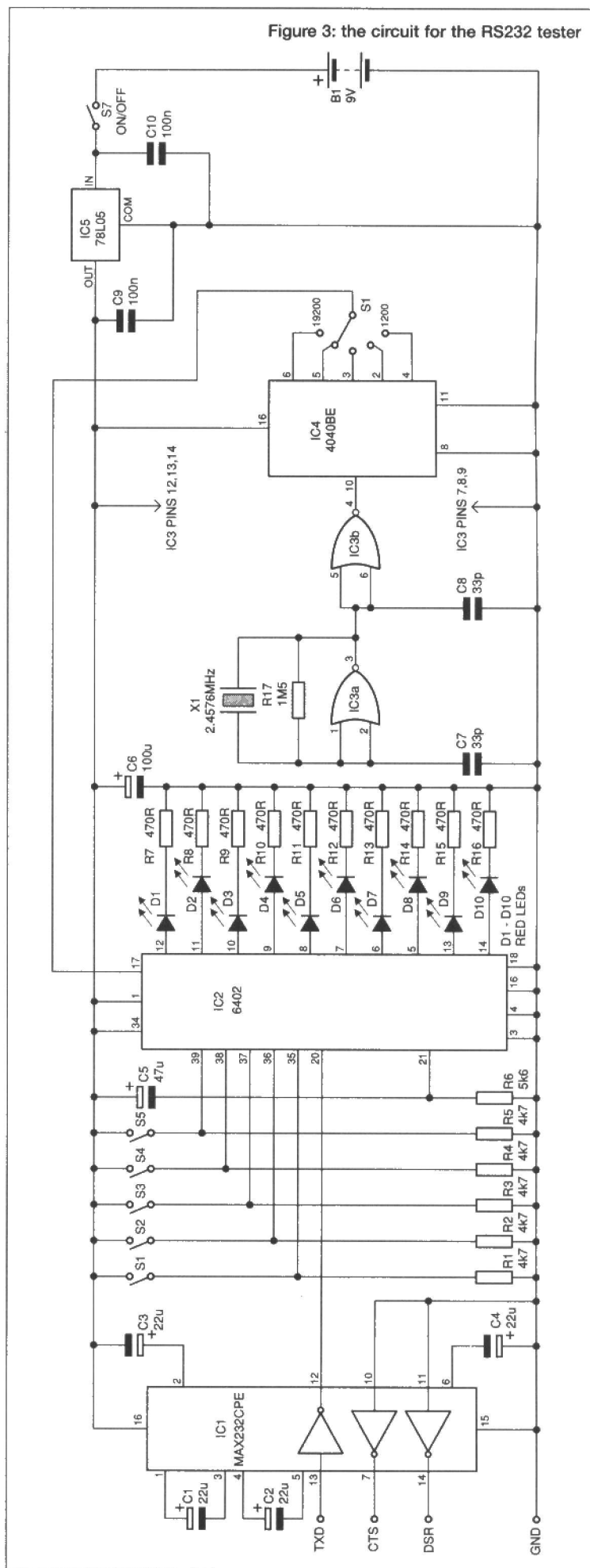


Figure 4: the component side of the stripboard panel. The board has 63 holes by 26 strips

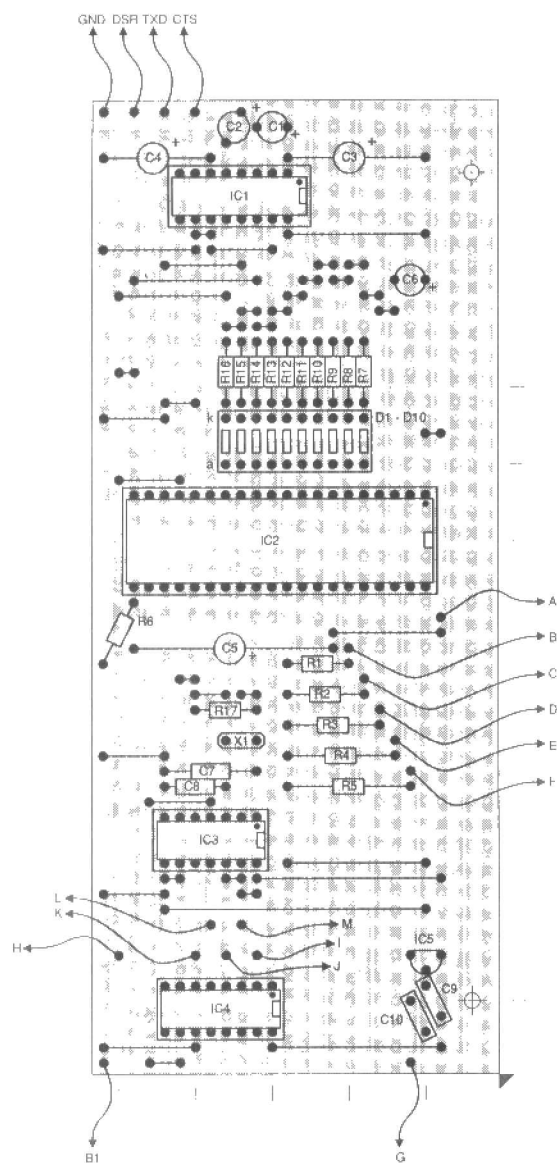
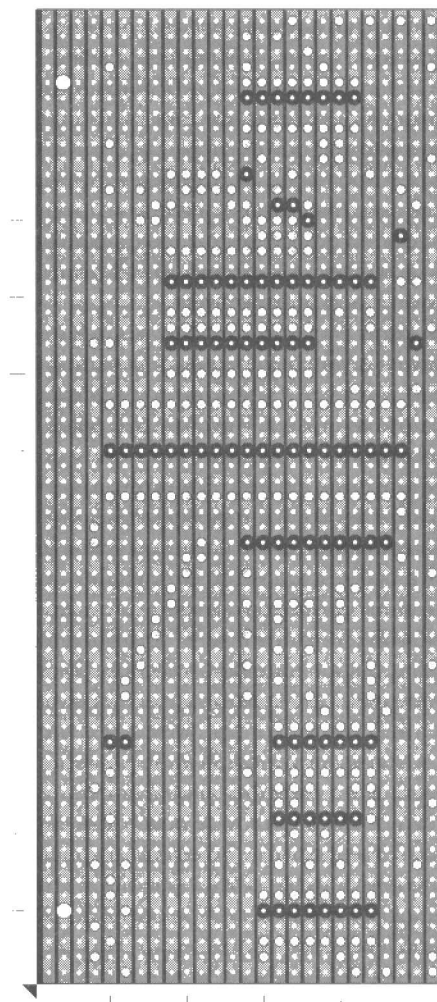
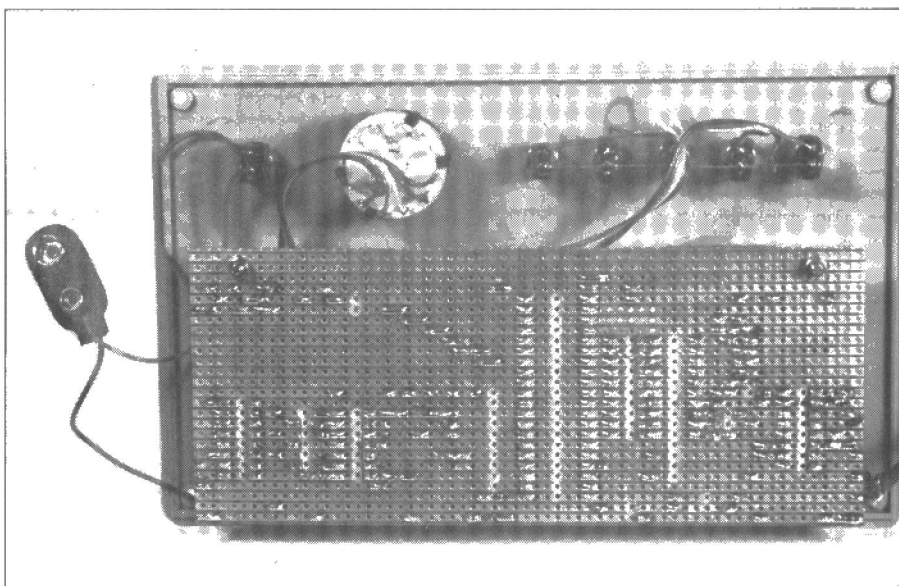


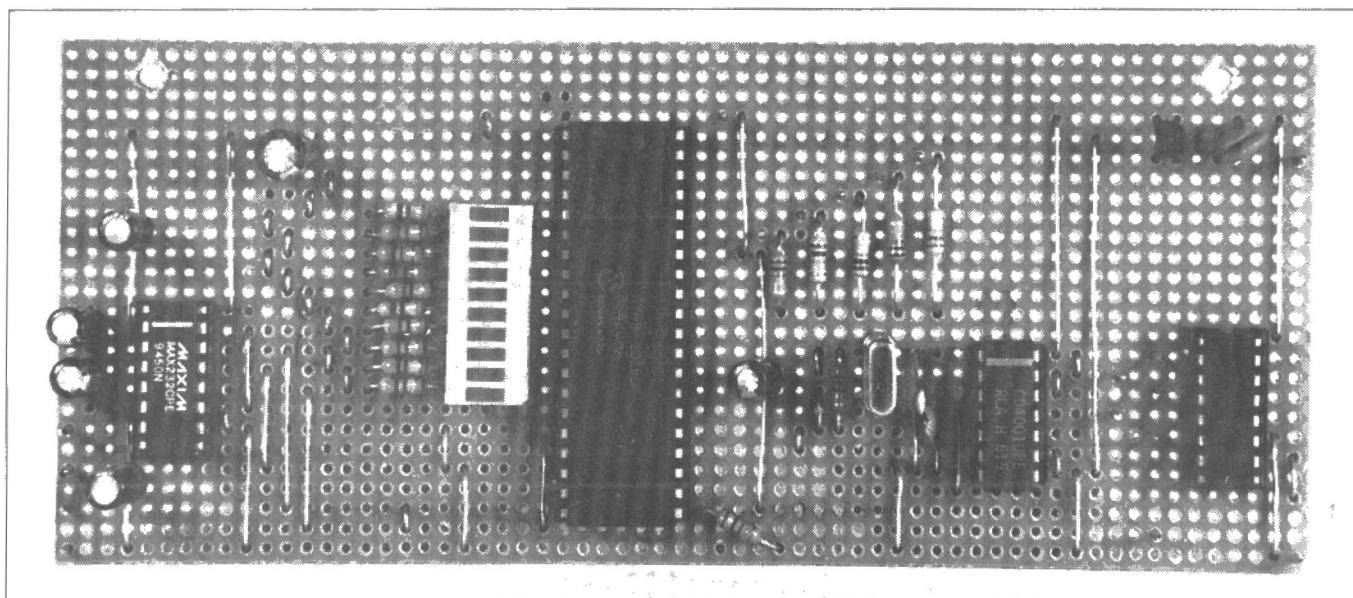
Figure 5: the underside of the stripboard



Next, the components and link-wires are added. This aspect of construction is largely straightforward, but with a substantial number of components and links to fit it is essential to proceed with care. Use holders for all four ics, as they are static-sensitive, and in the cases of IC1 and IC2 are not particularly cheap either. Do not fit them into their holders until the board and wiring have been completed.

A 10-LED bargraph display having a form of 20-pin DIL encapsulation is used for D1 to D10, and this should also be fitted in a holder. This is not due to any static problems, but is merely to raise it above the surface of the board so that it is clear of the other components. Otherwise it will not be possible to get it close to behind its window





in the front panel of the case. Determining the correct orientation for bargraph displays can be problematic, since the usual method of dip pin numbering is not normally used. The display used in the prototype has the manufacturers logo, etc. on the side of the case that carries the anode (-) pins, but this method might not be universal. In the absence of any means of checking the polarity, simply use trial and error to find the right orientation. Getting the display connected around the wrong way will not damage it.

X1 must be a miniature type having 0.2 inch (5.08 millimetre) lead spacing. This style is referred to in some component catalogues as an HC-49U case. It is connected to the board just like any other component, but try to complete the soldered joints reasonably quickly so as to avoid overheating the crystal. Overheating it could impair its accuracy, or in an extreme case could result in a lead becoming detached internally.

Be careful to fit the electrolytic capacitors with the correct polarity. Radial types are used in the prototype, but axial components are equally suitable for C3 and C5. To complete the board add the solder pins at the points where the off-board connections will be made. Tin the tops of all the solder pins with a liberal amount of solder.

One of the larger plastic boxes is needed to accommodate the 6.3 inch width of the component panel and the seven switches that must be mounted on the front panel. The removable lid of the case becomes the front panel, and the circuit board is mounted on the rear of this panel, as far towards the bottom as possible. The component side of the board faces forwards, and it is bolted in place using long 6BA or metric M3 screws. Spacers totalling about 18 millimetres in length are used to hold the tops of the components slightly clear of the front panel. A window for the display to "look" through is cut in the front panel. A rectangular cutout about 28 by 14 millimetres is suitable. This can be cut using a fretsaw or coping saw, an "Abrafile", or any miniature round file. It is best to cut just inside the perimeter of the rectangle, and then file the hole to precisely the required size using a miniature flat file. A piece of transparent plastic is glued in place behind the cutout.

The seven switches are mounted in a single row in the vacant area at the top of the front panel. The only other drilling is to make an entrance hole for the input lead in one side of the outer casing. A hole of about four millimetres in diameter should be suitable.

Wiring

The hard wiring must be completed before the component panel is finally fixed in place. This wiring is shown in figure 6, which should be referred to figure 4 (for example, point "B" in figure 6 is connected to point "B" in figure 4). Probably the neatest way of handling this wiring is to use a piece of six way ribbon cable to connect S6 to the circuit board, and another six way cable to connect S1-S5 to the board. S6 is a 12 way single pole rotary switch having an adjustable end-stop. In this case the end-stop is obviously set for five way operation. S6 should be a break-before-make switch, or it will short circuit two outputs of IC4 each time it is switched from one position to another.

Most serial ports use a 25 way male D type connector, and the connections to them are therefore made via a 25 way female connector. The only common exception is the nine way PC AT style serial port. Figure 7 shows connection details for both types of PC printer port. Compatibility with these two styles of serial port can be achieved by connecting the input of the unit to both types of socket. Alternatively, connect the unit to a 25 pin plug and use the standard "pigtail" adapter for operation with nine pin serial ports. The connections to the socket are made via three way screened cable, with the outer braiding carrying the earth connection. The inner conductors carry the connections to the TXD, CTS, and DSR lines. No

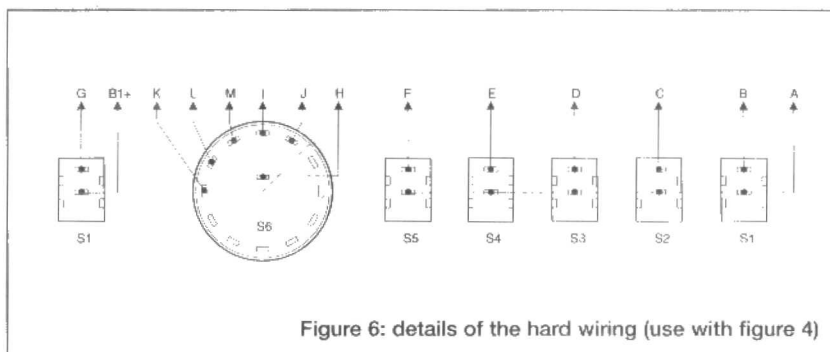
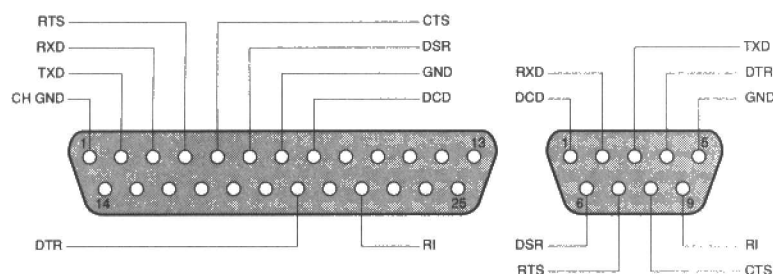


Figure 6: details of the hard wiring (use with figure 4)

Figure 7: connection details for 25- and 9-pin PC serial ports



settings, Windows settings, etc., to locate the source of the problem. If garbage is being transmitted, the problem is almost certainly due to a hardware fault in the sending device.

If the tester indicates that the sending device is sending valid signals, either the receiving device is faulty or has not been set up correctly. Again, check the settings on the printer or other peripheral to see if it is set for the required baud rate and word format. If data is transmitted correctly to the tester, but none is sent to the peripheral device, it is likely that there is a handshake problem. Is the cable suitable

connections are made to the terminals of the serial port. If it is difficult to obtain three way screened cable, use four way cable and simply ignore one of the inner conductors. Long connecting leads are acceptable with serial interfacing, and the input lead can be several metres long if desired.

In use

Assuming that the unit is not being fed with data at switch-on, all the LEDs in the display will be switched off. The appropriate baud rate is set using S6, and the required word format is then set up using S1 to S5. S1 should be open (off) if parity checking is required, or closed (on) if it is not. If parity checking is enabled, S5 should be on to select odd parity, or off to choose even parity. In most cases parity checking will not be required, so S1 would be set to the off position, rendering the setting of S5 irrelevant.

S2 selects the number of stop bits, and is off for one stop bit, or on for two stop bits. The number of data bits is selected using S3 and S4, as shown in the following table:

Data Bits	S3	S4
5	off	off
6	off	on
7	on	off
8	on	on

Rationalising things, in most cases eight data bits and no parity will be required. Therefore, set S1, S3, and S4 off, and S5 to either setting. These switches will only need to be altered if test a system using an unusual word format, such as one which only deals with ascii codes and uses seven data bits. S2 is switched off for one stop bit, or on for two stop bits. One stop bit is the most common these days, but two stop bits are not uncommon. S2 is therefore the only word format switch that is likely to need frequent adjustment.

It is better to test the port by sending a reasonably long file, rather than sending one character at a time. It is helpful to produce an ascii file of "U" characters, and using the block copy facilities of practically any word processor or text editor a substantial file can soon be built up. The "U" character is a useful one as it is 85 in decimal, or (more importantly) 01010101 in binary. This gives a distinctive on-off-on-off-on-off-on-off display, and will clearly show up any decoding errors. If the display shows decoding errors, try different baud rate settings and word formats in an attempt to discover whether the data stream is sound. It could be that the sending device is simply not transmitting using the expected baud rate and (or) word format, or it might be faulty and sending garbage. If the word format or baud rate are wrong, check the program

for the type of handshaking in use? In addition to the earth and signal wires, hardware handshaking usually requires CTS and DSR on the sending device to be wired to RTS and DTR at the peripheral device.

Even if hardware handshaking is not actually being used and the receiving device can handle a continuous stream of data, CTS and DTR on the sending device may have to be taken positive before any data will be sent. This is, of course, the method of pseudo hardware handshaking implemented by the tester. Software handshaking uses both RXD and TXD lines, and is outside the scope of this tester. In theory, at any rate, the hardware handshake lines are irrelevant if software handshaking is implemented. However, it might be worthwhile taking the handshake inputs of the sending device positive to see if this improves matters.

PARTS LIST For the RS232C Tester

Resistors

(All 0.25 watt 5% carbon film)

R1 to R5	4k7 (5 off)
R6	5k6
R7 to R16	470R (5 off)
R17	1M5

Capacitors

C1 to C4	22u 25V radial elect (4 off)
C5	47u 25V radial elect
C6	100u 10V radial elect
C7,C8	33p ceramic plate (2 off)
C9,C10	100n disc ceramic (2 off)

Semiconductors

IC1	MAX232CPE
IC2	6402 UART
IC3	4001BE
IC4	4040BE
IC5	78L05 5V 100mA regulator
D1 to D10	20 pin dil LED bargraph

Miscellaneous

S1 to S5,S7	SPST min toggle switch (6 off)
S6	12 pole 1 way rotary (set for 5 way operation)
B1	9-volt (PP3 size)
X1	2.4576MHz wire-ended (HC49U)

Plastic case about 184 x 115 x 63mm, 0.1 inch pitch stripboard having 63 holes x 26 copper strips, control knob, 14-pin dil holder, 16 pin dil holder (2 off), 20-pin DIL holder, 40-pin dil holder, 25 pin D socket, battery connector, 4-way screened lead, wire, solder, etc.

Simple low-cost digital frequency meter

A PIC-driven meter by MadLab

Our meter has the following features:

- * operating range from about 15Hz to 8MHz (sufficiently high to make the meter useful for troubleshooting digital circuits, microcontrollers etc.)
- * internal accuracy plus or minus 1Hz
- * 4 digits of displayed accuracy (enough accuracy for most situations)
- * adaptive (no range switch)
- * input conditioning amplifier sensitive to 50mV
- * input protection
- * crystal controlled (no need for calibration)
- * powered by a single 9V alkaline battery

The circuit is built around a member of the PIC family of microcontrollers from Arizona Microchip, the most junior member of that family, the 16C54. We hope to give some insight into the methodology of software design for microcontrollers, and for the PIC in particular. The challenge as so often these days was to achieve a solution with the minimum of hardware by moving the functionality into software.

Basing the circuit on a microcontroller, rather than opting for a conventional electronic design, gives a greater degree of flexibility. Software has a certain advantage over hardware in adaptability where it can be used: it is easier to change some lines of source code than to add another track to a pcb. Even so, it can be even harder to keep track of software behaviour and alterations than it is for hardware.

The PIC is an excellent microcontroller. It is robust, simple to interface to the outside world, and relatively simple to program. We've been using this chip for several years now and have never seen one damaged by static when being handled (less worry about earthing straps or whether one's clothes have synthetic fibres in them). We've seen them survive being placed into sockets backwards and power applied. We've even seen them pulled out and put back into their sockets with the battery connected without damage! We don't wish to encourage this kind of treatment, especially as static damage to chips can show up after a lengthy period of use, but it is a tribute to their robustness.

All processors have peculiarities in their instruction sets, and the PIC is no exception. There are only 33 instructions to learn, which is not too bad. One of the most confusing is the subtract instruction, which is actually an add instruction using the negative of the number. This reverses the carry flag from what one would normally expect.

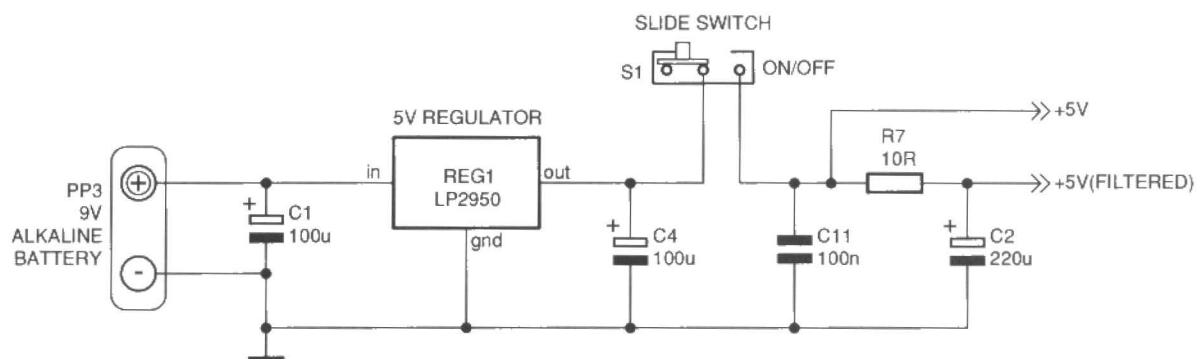
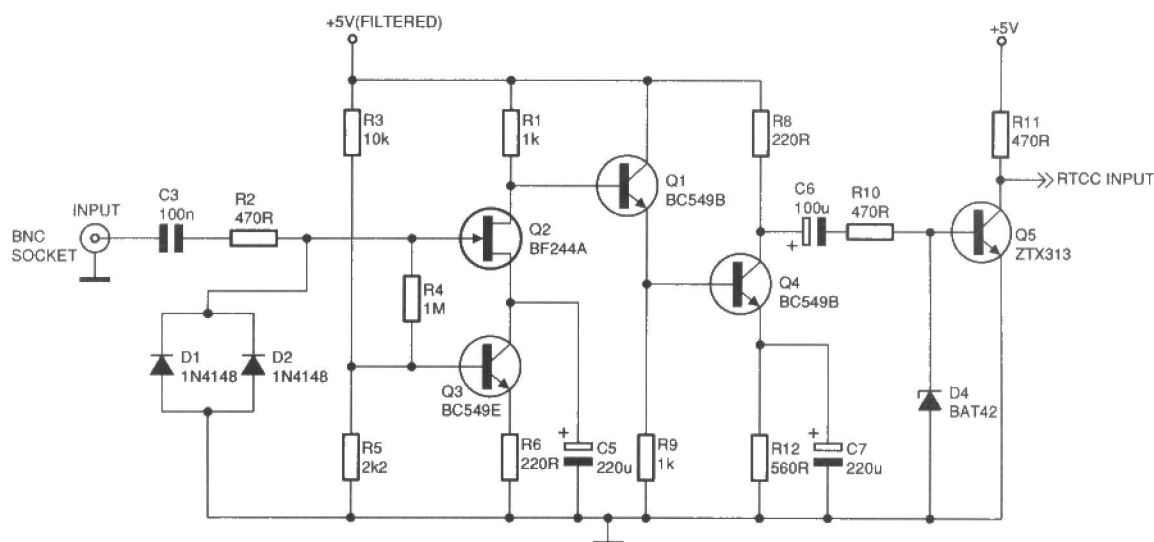


Figure 1: the circuit of the power supply

Figure 2: the circuit of the input amplifier



Mnemonics

Individual instructions are represented by mnemonics which are easier to remember than the binary codes that the processor actually understands. For example, the instruction `retlw k` returns from a subroutine with a literal value or constant placed in the working register. A software tool called an assembler converts the mnemonics (source code) into binary (object code).

The PIC 16C54 has 13 input/output (I/O) pins of which 12 are general purpose. These pins are used to drive four 7-segment LEDs that display the measured frequency. The remaining I/O pin is connected to an internal register in the PIC called the RTCC (real time clock/counter). This register can count either internal instructions or external pulses. In this project we are using its ability to count pulses. The RTCC pin is connected to an external probe for the meter via some circuitry to condition the input signal. The RTCC can trigger on a rising or a falling edge, but in this design we have conventionally selected triggering on rising edges. There is also a prescaler associated with the RTCC which can prescale the input to the counter from 1:2 to 1:256.

The desired accuracy of plus or minus 1Hz rules out using an RC oscillator to drive the microcontroller. A crystal or ceramic resonator must be used. The frequency meter must measure up to an 8MHz input signal, so the processor needs to be fast. Resonator versions of the chip run up to 4MHz, and crystal versions up to 20MHz, therefore the high speed version running with a 20MHz crystal was chosen. Each PIC instruction takes 4 clock cycles to execute, so a 20MHz PIC has a performance of 5 million instructions per second or MIPS (although each instruction doesn't do very much by itself, it is still a very impressive figure).

We measure the frequency of a signal by counting the number of pulses (cycles) over a fixed period of time, usually 1 second. This gives a reading accurate to plus or minus 1 Hz. For high frequencies (above 10kHz) the meter can be made more responsive by timing over a shorter period, say one-eighth of a second. This reduces the accuracy to plus or minus 8Hz, but because only 4 significant digits are displayed, this doesn't matter.

The RTCC can't count more than one pulse per instruction cycle (per 4 clock cycles). With a 20MHz crystal it can count a maximum of 5 million pulses per second. For signal

frequencies above 5MHz therefore the prescaler must be used. This has the effect of dividing down the input frequency to the counter. With prescaling of 2 the frequency meter can cope with up to 10MHz signals.

Design Goals

One of the design goals was to dispense with range switches or the equivalent. Consequently, the software had to be adaptive to whatever input signal frequency it is fed with, from a few tens of Hz to MHz - a range of six orders of magnitude! The first problem was how to display such a range of frequencies using just four digits (that is, without being able to display the units, whether Hz, kHz or MHz). The solution was to always display the signal frequency in kHz with the position of the decimal point effectively indicating the units. Table 1 gives the displayed readings for the range of frequencies. A more sophisticated (and expensive) approach would be to use an alphanumeric LCD display which could display the units as well as the digits.

Underflows (frequencies less than 1Hz) or no signal at all are displayed as a single zero, and overflows (frequencies greater than 8MHz) are displayed as the letter 'E' (for error).

Table 1 - How the frequency meter displays different frequencies

Frequency	Display
less than 1Hz	0
1Hz	0.001
10Hz	0.010
100Hz	0.100
1.000kHz	1.000
10.00kHz	10.000
100.0kHz	100.000
1.000MHz	1000.000
more than 8MHz	E

One of the arts of circuit design using small microcontrollers is to make each of the I/O pins on the chips do a number of different jobs (as there are so few of them). In this design the same set of eight pins drives four 7-segment displays, each of which could be displaying a different digit at the same time.

This uses a technique known as multiplexing whereby only one of the 7-segment displays is actually switched on at any one time. The software very quickly displays a digit on each of the four displays in turn but, because this happens a thousand times a second, you don't notice any flicker. This phenomenon is due to our 'persistence of vision' - any flicker faster than 72Hz can't be perceived by the human eye. The other four I/O pins control which 7-segment display is currently enabled.

This technique complicates the software, because the display multiplexing needs to happen all the time the software is counting pulses. The two processes must be interleaved and because of the need to know the exact number of instructions executed this requires careful planning.

Reduced instruction set

As mentioned above, the RTCC register of the PIC can either count internal instructions or external pulses. If it is used to count internal instructions, it is effectively acting as a clock (and so can measure time). As however we are using it to count pulses, we must use some other method for measuring time - in this case, by manually counting the number of instructions that are executed. This is a laborious process, but is simplified because the PIC is a reduced instruction set computer or RISC. This means that has a small number of simple instructions (no fancy addressing modes here) that the processor can decode and execute very quickly. The

advantage from our point of view is that all instructions execute in the same amount of time (more accurately, all instructions that don't cause a program branch execute in four clock cycles, all branch instructions in eight clock cycles). This means that to work out how long a fragment of code takes to execute you simply count the number of instructions.

The number of clock cycles in a loop gives the timing resolution of a process. For example, suppose some code is timing how long it takes for an event to occur. If the loop which polls the state of the event takes 10 microseconds to execute, when the event happens the worst case is that the software becomes aware of that fact 10 microseconds later. So it is important to make timing loops short and efficient.

A key concept here is 'equal path lengths': whatever path the processor takes through a piece of code (and remember that a processor usually jumps about all over the place within its loops and subroutines), the total number of clock cycles elapsed must be the same whatever the different conditions that prevail. For example, consider the fragment of code below that increments a 16-bit counter. The 16-bit counter is implemented from two 8-bit registers because the PIC doesn't have any 16-bit registers. Let's call these two registers counter_lo and counter_hi. The fragment of code increments the combined 16-bit counter by adding one to the low byte and if this causes the byte to roll over from 255 to 0 (since 255 is the largest number that can be stored in a single byte), then adding one to the high byte.

```
incf counter_lo
skpnz
incf counter_hi
```

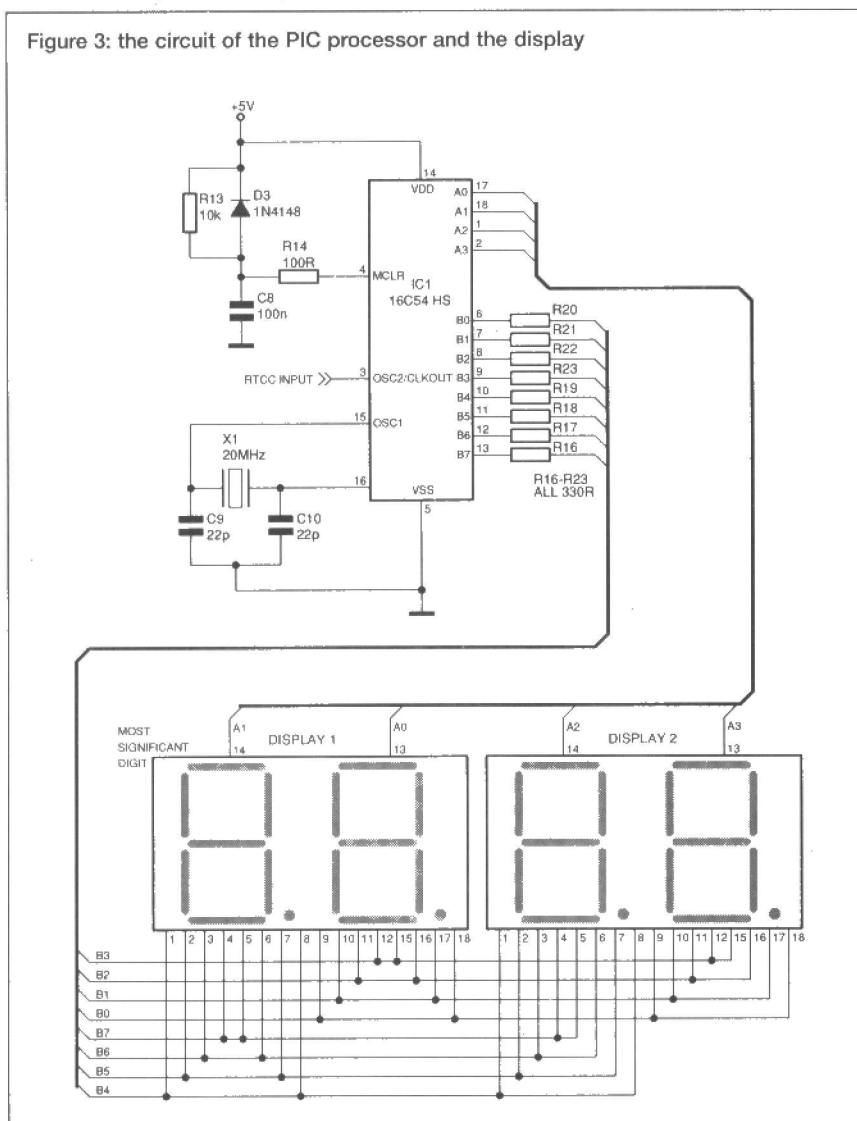
The first instruction adds one to the low byte. If the result of this operation is not zero (that is, the register has not rolled over) then the instruction to increment the high byte is skipped. The skpnz instruction skips the next instruction if the result of the previous instruction was not zero (skips if the nz flag is set). A nice fact about the PIC is that this fragment of code takes the same amount of time to execute whether the low byte rolls over or not. The first instruction always takes four clock cycles. If the nz flag is set then the skip takes place and the second instruction takes eight clock cycles (because a branch has taken place). If the nz flag is not set then no skip occurs and the second instruction takes a normal four clock cycles, and the last instruction also takes four cycles. So in both cases the code fragment takes 12 clock cycles to execute.

This technique is applied to the main loop of the program. The code that multiplexes the display and polls the RTCC always takes a constant (and known) number of clock cycles to execute and thus can form the basis for measuring time.

Using a second

The timing loop for the frequency meter should be of a length such that a second can be conveniently timed using a 16-bit loop counter. A timing loop of 20 microseconds needs to be

Figure 3: the circuit of the PIC processor and the display



iterated 50,000 times per second. This value fits nicely into 16 bits (and is also a multiple of 8 which is a requirement for timing one eighth of a second with the same loop).

The RTCC register is 8 bits wide and can only count up to 255 pulses. We need to be able to count many more pulses than that in a second. The register is extended by software into a 24-bit counter which can count up to 16 million, which is enough for our purposes. The timing loop looks at the current value of RTCC and compares it to the previous value. If the previous value had its most significant (left-most) bit set and this bit is now clear then the counter must have rolled over (for example going from 255, which is 11111111 in binary, to 0). When the RTCC rolls over the high 16 bits of the 24-bit counter need to be incremented. The low 8 bits are simply a copy of the RTCC register.

If more than 128 pulses occur between polls of RTCC, pulses will be lost. This sets the upper limit to the frequencies that can be measured. A timing loop of 20 microseconds is equivalent to a frequency of about 6MHz. This is a little too low for the specification, so use is made of the RTCC prescaler at high frequencies. Prescaling of 1:2 effectively halves the input signal frequency and takes us safely above 8MHz. The prescaling must be compensated for in the software by an appropriate multiplication.

Subroutine

The subroutine that drives the 7-segment displays uses a 'lookup' table, which contains the patterns of light for the individual LED segments that represent the decimal digits 0 to 9. The PIC uses a rather strange way of implementing a lookup table. A list of return-from-subroutine (retlw) instructions is used. This instruction puts a constant value (a literal) into the working register of the PIC. So getting a value from the lookup table involves calling an address within the table as if it were a subroutine. The source code however can be made more readable by defining a set of macros to hide the PIC syntax used.

table	macro label	; define lookup table
label	addwf PC	
	endm	
entry	macro value	; define table entry
	retlw value	
	endm	
index	macro label	; index lookup table
	call label	
	endm	

The first macro is used at the head of a lookup table and gives it a name. The instruction addwf PC offsets the program counter by the value in the w register (the index into the table), thus jumping to the appropriate retlw instruction. The second macro defines an individual entry in the table and disguises the retlw

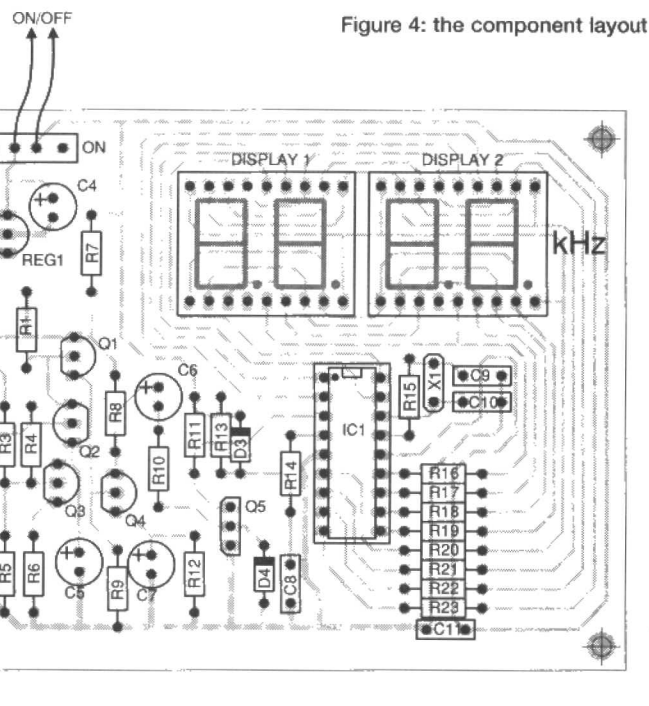


Figure 4: the component layout

instruction as discussed above. The third macro is used to fetch a value from the table. The working register is loaded with the index of the entry in the table prior to calling the first instruction in the table (which contains the addwf PC instruction).

A complete lookup table is therefore constructed as follows:

table MyTable

entry 12h
entry 34h
entry 56h

....

In this design four different lookup tables are used for the four 7-segment displays. This simplifies the layout of the pcb at the expense of a marginal increase in the complexity of the software.

You may have noticed that we haven't given a flow chart for the software. It is more instructive to study the actual source code for the program which is documented more comprehensively than a flow chart would be. The documented source is available on floppy disk from MadLab (see Component Sources below).

The circuit

The circuit of the frequency meter can be divided into three main parts - the power supply, the input amplifier, and the digital circuitry.

The power supply

See figure 1. The meter is intended to be portable and can be powered by a 9V alkaline battery. A voltage regulator is used to stabilise the supply rail to 5V. It is important for accuracy that the microcontroller has a good power supply and the regulator does this very well.

The digital rail is expected to be noisy due to the multiplexing of the LED displays and the switching of relatively high currents (40mA). Components R7 and C2 form a low-pass filter of around 100Hz and isolate the voltage supplied to the input amplifier from the noisy digital rail.

Note that if the meter is powered by a battery then it must be a good quality alkaline battery, such as a Duracell.

The input amplifier

(See figure 2). The input amplifier is the interface between the input signal and the PIC microcontroller, and its function is to condition the signal before it passes to the RTCC pin. It will convert any periodic signal (sine, triangular, square wave etc.) with a peak to peak amplitude of at least 50mV into a clean 5V TTL-level square wave as required by the RTCC input. The amplifier has a high input impedance to minimise its effect on the input signal.

The first stage of the input amplifier is based around a FET (TR2) which uses constant current biasing. Constant current biasing has the advantage that the drain current does not depend on the characteristics of the FET which can vary widely. This means that the dc levels throughout the circuit can be accurately predicted making the design work easier.

The design starts with the choice of FET. A BF244A was selected because of its low and narrow range of drain current IDSS (2 - 6.5mA). A value of 1mA was chosen for the constant current biasing (below IDSS min) and this ensures that all BF244A FETs will have the same dc operating point regardless of their variation in transconductance.

Resistors R3 and R5 form a voltage divider and provide a fixed voltage of 0.9V at the base of TR3. The emitter is therefore at $0.9 - 0.65 = 0.25V$. This voltage falls across the 220R emitter resistor causing TR3 to provide a constant current of $(0.25/220) =$ approximately 1mA. The drain resistor R1 has a value of 1k and causes a voltage drop of 1.25V. The voltage at the drain of the FET is therefore fixed at 3.75V. Capacitor C5 provides an ac path to ground, bypassing the constant current source, and allows ac voltages to develop across the drain resistor R1.

The voltage gain of the FET stage is not predictable since it depends on the transconductance of the FET and this parameter has a spread of values. Measured values of voltage gain at the drain of TR2 were between 1 and 2.

The output impedance of the FET stage is around 1kohm, and an emitter follower is used to connect the next stage which is a common emitter amplifier. Each stage is dc coupled and so the base of TR4 sits at $3.75 - 0.65 = 3.1V$. The emitter of TR4 is at $3.1 - 0.65 = 2.45V$. The emitter resistor R12 has a value of 560R giving an emitter current of approximately 4.4mA. The collector resistor R8 has a value of 220R and gives a voltage drop of around 1V.

The gain of this stage is $R8/r_e$ where r_e is the intrinsic emitter resistance. The voltage gain is about 40.

The signal from the collector of TR4 is converted to a 5V square wave using the switching transistor TR5. Capacitor C6 provides ac coupling to the base resistor R10 and diode D4 clamps the signal to the ground rail.

The voltage gain of the input stage is up to 80 and has a flat response from 100Hz to 10MHz. Resistor R4 determines the input impedance of the amplifier. A value of 1Mohm was chosen and this produces a fixed impedance up to 30kHz. The impedance then reduces by 10 for each decade the frequency is increased, that is, at 300kHz it is 100kohms, and at 3MHz is 10kohms.

Input protection is provided by R2, D1 and D2. D1 is a silicon diode and clamps the input to ground (-0.6V). Resistor R2 limits the current during an over-voltage condition.

The digital circuitry

A standard power-on reset circuit is provided for the PIC. Components C8 and R13 hold the voltage at MCLR near zero volts until the PIC's oscillator has stabilised. Resistor R14 protects against C8 discharging through the MCLR pin, and

diode D3 enables the capacitor to discharge quickly when power is removed.

The microcontroller clock circuitry, consisting of C9, C10, R15 and X1, is also very standard and is straight from the microchip data sheets.

The four 7-segment displays share driver resistors (R16 - R23), one per LED segment (eight in all, including the decimal point). The displays don't have to be wired like to like - in other words all the A segments, all the decimal points etc. don't have to be wired together - and it is easier to lay out the tracks on the pcb without this constraint and it is not hard to have a different lookup table for each display in the software. The displays are common cathode and are activated by pulling the common pin low and then writing 1s or 0s to the individual segments. If the common pin is high then no current can flow. In this way, one display can be activated at a time.

Construction

Construction is straightforward. First fit, solder and trim the resistors, then fit and solder the capacitors, paying attention to the polarity of the electrolytics. Next fit the diodes, transistors and the regulator. Note that the Schottky diode may not be marked with a type number. The symbols on the pcb silk indicate the orientation of the transistors and regulator.

Next fit the IC socket (notch against notch) and the dual 7-segment displays (note the decimal points on the pcb symbol). Take care to avoid solder bridges between the pins. It is by far preferable to use an ic socket with a PIC, and not solder it directly to the board. Suppose to have a software error, or want to make some change of your own? Unsoldering large ics to replace them is very tricky indeed, besides the risk of damage to the board. Finally fit the crystal, slide switch, BNC socket, and battery connector. The latter has support holes drilled on the pcb. Feed the battery snap leads up through the support holes from the metal side of the board and then down the solder holes.

Don't fit the chip into its socket until you have checked your construction. Check that all the components have been inserted the right way round and that there are no dry joints or solder bridges. Then follow the procedure in Circuit Testing.

Circuit testing

Without the PIC in place the analogue circuitry can be tested. Apply power to the board and check for the following dc voltages:

- * 5V at the plus side of C4
- * Around 3.8V at the base (middle leg) of TR1
- * Around 3.1V at the base of TR4, around 3.9V at the collector, and around 2.45V at the emitter
- * Around 0.9V at the junction of R3 and R5

Apply a test signal to the input (about 100mV at 1KHz). Look for the presence of the signal at the output of the amplifier (the collector or top leg of TR5) as a clean square wave.

If the board checks out as above then fit the chip into its socket, notch against notch. The legs of the chip may need bending a little, do this carefully with your fingers. No special static precautions are necessary.

The software includes a power-on self-test. All the LED segments are turned on for about a second. If you see this then you know the power supply is ok, the processor is oscillating, and the multiplexing is working. After the self-test the display is blanked and then, if no input signal is present, 1 second later a single zero is displayed.

Insert the test signal again. If everything is working properly the meter will display the signal frequency.

A standard oscilloscope-type probe can be connected to the BNC socket. These probes generally have a crocodile clip attached. This should be connected to an earth point (0V) on the device to be tested.

The meter should be turned off when not being used as the LEDs draw a fairly large current. It could be connected to a mains power supply for bench use (supplying between 5 and 24V dc). The current drain is normally about 50mA.

Circuit variations

D2 can be left out entirely. This improves the performance of the meter by increasing its input impedance, but at the cost of losing the input protection.

A useful addition to the circuit at high frequencies (above 1MHz) is a 100pF ceramic capacitor in parallel with resistor R10. This helps TR5 to switch on and off more quickly. The capacitor can be soldered directly across R10.

If the meter is being powered by a mains power supply the display can be made brighter by reducing the value of the driver resistors R16 - R23, to 220R. The suggested value of 330R is designed not to draw too much current from a battery. A cheaper regulator such as a 78L05 can be used if the meter is to be exclusively mains powered.

Casing

With regard to casing the project, almost any kind of box of a reasonable size will do that has a cut-out for the display. Personally we feel that these kinds of projects don't especially need cases. It is often more attractive for the workings to be on show. Not using a case also encourages one to be neater with one's construction. If the meter is not cased then rubber feet can be glued to the corners. However, if you are going to move your meter around much, or want to avoid things being stood or dropped on it, it is better to put a case on it.

The best size is slightly larger than the pcb. Maplin sell a suitable 2-part AB10 aluminium case (part LF11M) with dimensions 133mm x 102mm x 38mm. Mount the pcb in the bottom part of the case using spacing pillars at the four corners of the board (fitting 4mm holes). Cut a hole in the side of the case for the BNC socket. You can run a short screened wire from the socket to the pcb or solder the socket to the pcb and use the socket's nut to hold the pcb firmly to the case. Cut out a section in the top part of the case directly above and slightly larger than the 7-segment displays. Glue a piece of red cellophane or gel on the inside of the case over the cut-out. Finally mount an on-off toggle switch on the case and connect wires from the switch to the pcb (S1).

Applications

A good use of the frequency meter is to calibrate other equipment. For example, a signal generator that doesn't have its own digital display. The meter will show the exact frequency being produced by the signal generator.

Texas Instruments manufacture a series of light sensors (such as the TSL220) that produce an output frequency depending on light intensity. They are very easy to use requiring just one external capacitor. A light meter combining one of these sensors with the frequency meter could accurately measure irradiance over a three-decade range.

Attach a crystal microphone to the frequency meter and you have a guitar tuner. The meter will display the exact

frequency being played on a musical instrument. You can easily tune the instrument with reference to a table of note frequencies.

Component sources

Most of the components used are fairly standard. The 7-segment displays can be obtained from Maplin amongst others (Maplin part BY68Y). The pre-programmed PIC is available from MadLab, 149 Rose Street, Edinburgh EH2 4LS for £7.50 (inclusive of P&P). A professionally-manufactured printed circuit board with tinned tracks and silk-screened legend can be obtained from MadLab for £5.00 (again inclusive of P&P). A high-density 3.5in diskette for PC compatibles containing the fully-documented source code and associated object files is also obtainable from us for £2.50. A complete kit containing the pcb, all the components, the PIC and the diskette is available for £22.50 (inclusive price). Please make cheques and POs payable to MadLab Ltd. Orders will be dispatched within 28 days.

The PIC source code is also available from MadLab's World Wide Web site. The address is <http://www.madlab.org> if you have access to the Internet.

PARTS LIST for the Frequency Meter

Resistors (all one-quarter watt 5% carbon film)

R1,R9	1k
R2,R10,R11	470R
R3,R13	10k
R4	1M
R5	2k2
R6,R8,R15	220R
R7	10R
R12	560R
R14	100R
R16-R23	330R

Capacitors (electrolytics 2.5mm spacing, others 5mm)

C1,C4,C6	100u electrolytic 16V
C2,C5,C7	220u electrolytic 16V
C3	100n miniature polyester
C8,C11	100n ceramic
C9,C10	22p ceramic

Semiconductors

TR1,TR3,TR4	BC549B npn transistor (or BC547B, 48C etc.)
TR2	BF244A N-channel JFET
TR5	ZTX313 npn switching transistor
D1-D3	1N4148 silicon diode
D4	BAT42 Schottky diode
REG1	LP2950 5V regulator
IC1	18-pin DIL socket + PIC16C54 HS/P microcontroller
DISPLAY1,2	0.56in dual 7-segment LED display, common cathode

Miscellaneous

X1	20MHz crystal, HC-49/U case
S1	SPDT miniature pcb vertical slide switch
INPUT	BCN pcb socket
BATTERY	PP3 battery snap
	4 x pcb pillars or self-adhesive rubber feet

Experimenting with Video

PART 2

A digitally controlled mixer/fader

In this issue Robin Abbott presents the first half of the video mixer/fader to accompany last month's sync separator.

This month we will look at a project based on last month's video sync separator. This is a video mixer and fader. The specifications for this project are as follows:

- * It offers 12 different slide wipe and fade patterns, with considerable scope for other patterns to be generated by further development of the control program.
- * Selection of pattern and fade control by four-button keypad and dual seven-segment display.
- * Automatic fade/wipe by push button control.
- * Control of fade/wipe speed from less than 1 second to around 20 seconds.
- * All effects controllable by a PC on a standard serial port, allowing programmed fade/wipe effects.
- * Uses a PIC microcontroller to reduce costs.

This project is interesting, not only in its own right, but also for the insight it can offer into the use of real-time computer-controlled systems, particularly those for video control. All the software in the project is available in source code commented form to assist those who wish to understand its operation, or for further development.

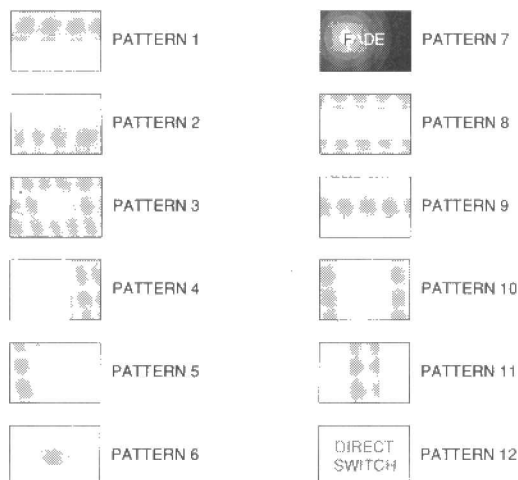


Figure 1: fade and wipe patterns

Operation of the mixer

The standard mixer offers 12 fade/wipe patterns. These are illustrated in figure 1. The black area on the figure shows the direction that the wipe will take. For example, fade pattern 3 wipes a black area from the right of the screen towards the left; if there is an input on channel B then channel A will wipe to channel B from left to right. If there is no input on channel B then the screen will wipe to black from right to left.

The mixer/wiper has four pushbutton controls and a rotary speed selection control. The four pushbuttons are: pattern up, pattern down, start fade, and start unfade. To select a pattern the pattern up and pattern down buttons select the pattern number which is displayed on the two-digit display.

Once the required pattern is shown, then the start fade button will put the screen to full brightness and then will start the fade. Similarly, the start unfade button will black the screen and then return it to full brightness using the selected fade/wipe pattern.

During a fade or unfade the pattern up and down buttons may be used to stop the current action, which can be used, for instance, to set black bars at the top and bottom of the screen to give a letter box wide screen effect. Another possibility is to set a black horizontal border at the extreme top edge of the screen to disable copy protection on commercial videos (for legal uses only).

The decimal points on the displays are also used, as shown in figure 2.

The rotary speed control is used to select the fade speed. The actual speed of the fade depends on the chosen effect. For example, pattern 1 which is a line by line fade will be twice as fast as pattern 8, which fades two bars from each end of the screen at the same time. The reason for this is that it achieves the maximum resolution of fading at any speed (resulting in the smoothest fades), and in practice is also easier to program.

The use of a PC control for the display is shown later in this article.

DISPLAY 1 DECIMAL POINT	DISPLAY 2 DECIMAL POINT	MEANING
OFF	OFF	NO VIDEO SIGNAL PRESENT
ON	ON	VIDEO SIGNAL PRESENT, NO FADING UNDERWAY
OFF	ON	FADING (OR UNFADING) OPERATION UNDERWAY
ON	OFF	FADING (OR UNFADING) OPERATION PAUSED

Figure 2: use of decimal points on the 7-segment display

Circuit and theory

The circuit diagram of the project is shown in figure 3. The heart of the project is the PIC16C74 microcontroller, described in the separate panel. This device controls the analogue paths used in the project, handles the display multiplexing, and provides two analogue voltages used for control of fading and side to side sliding. The serial interface is also handled through the 16C74.

The sync separator board

The sync separator board shown in last month's article forms the switching and fading capability for this project. The frame and line valid signals are used to indicate the position within the line and frame of the video signals to control the switching. The VGAIN input to the board is used to control the fading of the input channels, and the direct select B input SELECTB logic signal is used to switch between signals for the wipe effects.

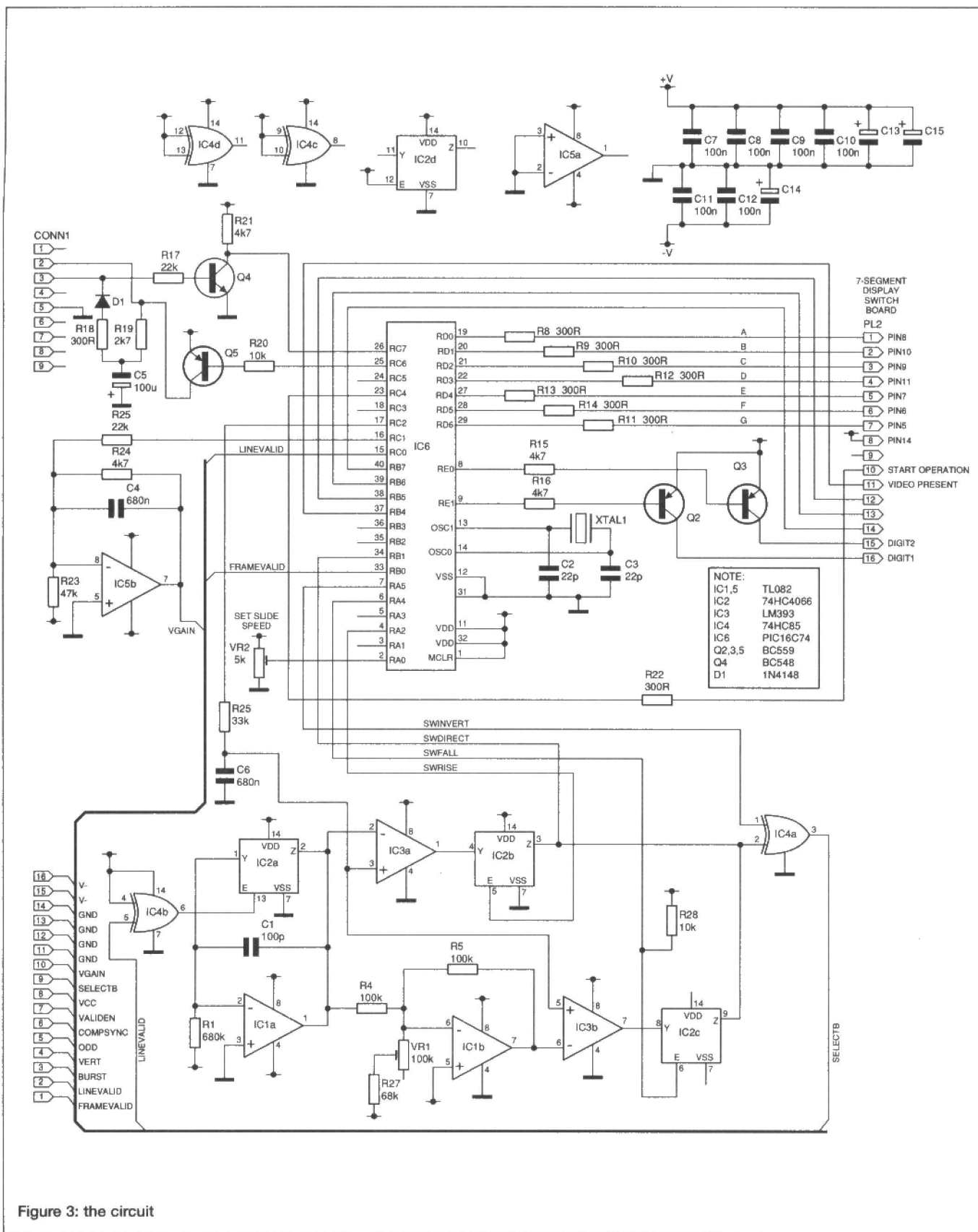
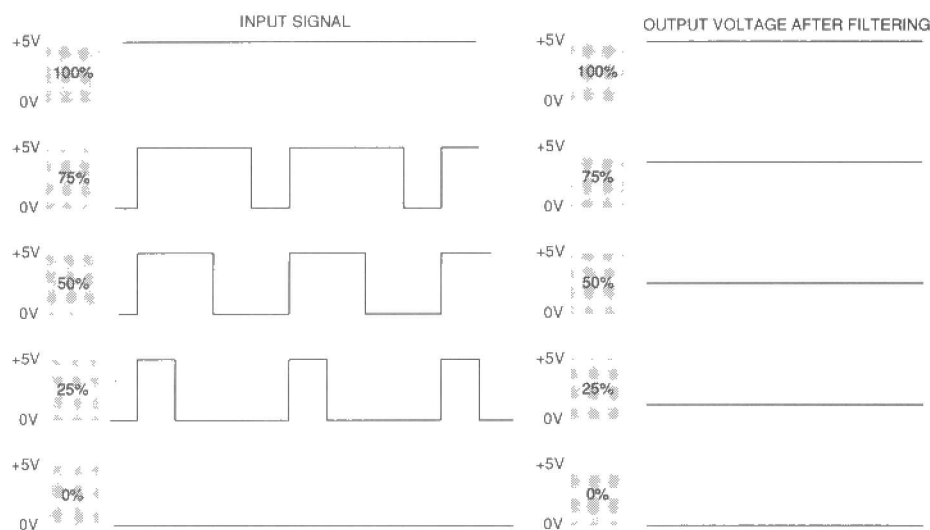


Figure 4: pulse wave modulation (PWM) waveforms. The PWM output changes duty cycle from 0 percent to 100 percent in single steps (PIC16C74 allows up to 10 bit resolution in some applications)



The direct control of the video signal, accomplished through the SELECTB input on the sync separator board goes low to select input A, or high to select input B. The PIC has two direct controls over the video signal using SELECTB. These are called SWDIRECT, and SWINVERT. SWINVERT simply turns on an inverter on SELECTB. The SWDIRECT signal is wire-OR'd with the signals produced by the horizontal effects circuitry, to achieve this the SWDIRECT signal is only ever driven low, or to a high impedance state, this is achieved using the tri-state control port on the PIC.

Vertical wipes

The vertical effects require the video signal to be switched on and off during the frame. For example to produce a black bar along the top of the screen (pattern 1) then the video signal must be turned off at the start of the frame, and then turned on at some point during the frame. For effects with a bar at the top and bottom of the screen, such as pattern 7, then the video signal must be turned off again further down the frame. This effect is handled entirely within the PIC. To look in detail at a particular pattern, we will consider pattern 7 (the letterbox effect).

You may recall that the sync separator project shown in last month's article provides a line valid signal which goes low during the period of the line sync pulses and colour burst signal. This signal may be used as a line counter during the frame, and is connected to a 16-bit counter (TIMER 1) inside the PIC, the PIC may be set to produce an interrupt when this counter overflows. At the start of the frame TIMER 1 is set to a negative value, and the video signal is turned off. During the frame TIMER 1 increments once on each incoming video line, eventually it overflows and causes an interrupt. The interrupt handling routine turns the video signal on, and loads another negative value into TIMER 1. When the timer overflows again the video signal is turned off for the lower black bar. No further action is taken until the next frame.

To cause the bars to slide up and down, the values loaded into TIMER 1 during the frame are changed at the end of each frame. Slower slide effects are created by changing the value in TIMER 1 less often.

Horizontal wipes

The horizontal effects have to be generated much more rapidly as video switching must occur during the 64us available during a line. Although a software solution may be possible, it would require a fast processor and would occupy a very significant amount of processor time in line timing. For this reason the horizontal effects are generated by analogue based techniques. Last month we looked at horizontal wipe effects using a monostable. This would be possible in this project, but the monostable would have to be voltage controlled. In addition to this the effects with bars at each edge of the screen require two switches operating symmetrically across the line. This is not easy to accomplish with monostables.

An alternative method was chosen for this project. A triangle wave is generated, which is reset to 0V at the start of the line, and which then rises through the period of the line. This is achieved by using an integrator which is reset at the start of each line by using an inverted form of the line valid signal from the sync board. This is used to short out, and reset the integrator capacitor. The components which achieve this are IC1a and IC2a. To obtain a symmetric switching effect, the output of IC1a is fed to an inverter and summer, IC1b which produces an inverted triangle wave. The symmetry of the signal is controlled by variable resistor R6 - the only preset control in the project.

To switch during the line period, two comparators (one for each triangular waveform) are employed. The comparator used is the LM393 which is a dual device with a common collector output. A fixed reference voltage is used by the comparators which switch the video signal when the triangular waveforms reach the same level as the fixed reference voltage. By changing the reference voltage the switching point may be controlled, and the wipe effect is generated across the line.

The voltage used on the comparators is generated by the PIC, and uses one of its pulse width modulation outputs. The use of a PWM signal to generate a variable voltage is shown in figure 4. The PWM output is used in 8-bit mode to give 256 voltage levels across the screen, which provides a

smooth wipe effect. The PWM output is smoothed by R25 and C6 which are chosen to filter the 20kHz PWM signal, but to allow the voltage to change in steps at frame intervals.

The outputs of the waveform comparators are wire OR'd with the SWDIRECT signal from the PIC. The outputs of the comparators are enabled when required using analogue switches IC2b and IC2c. These enabling signals are driven directly by the PIC on signals SWFALL and SWRISE. Figure 5 shows the waveforms in the horizontal switching circuit.

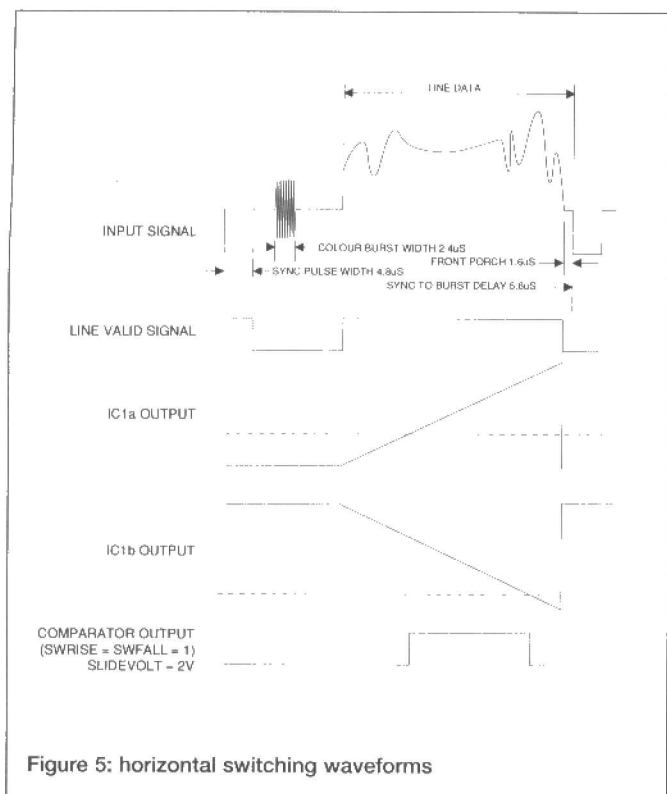


Figure 5: horizontal switching waveforms

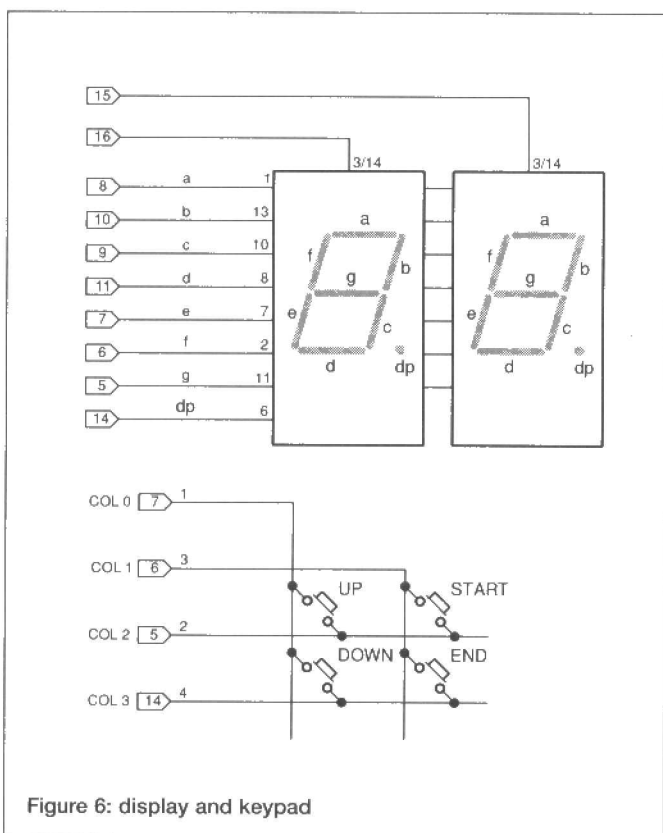


Figure 6: display and keypad

Direct frame fade

To fade the entire video frame up or down the VGAIN input on the sync board is used. The second PWM channel on the PIC is used to provide this voltage. Note that it would have been possible to use the same PWM channel for the horizontal wipes, but this would preclude the use of combined horizontal wipes and frame fades simultaneously. The circuitry around IC5b is an active low pass filter, which also scales the PWM voltage which nominally varies from 0 to 5V, and converts it to a level suitable for the VGAIN input of the sync board - from -0.5V to +0.5V. Please note that there is an error in the circuit diagram for the sync board, the VGAIN + and - inputs to the EL4095 device are shown in reverse, and the VGAIN input is inverted so that an input of +0.5V results in channel B being selected on the sync board.

Keypad and display

The keypad and display are as simple as possible to keep the cost as low as possible. A 2-digit 7-segment display is used with a multiplexed drive. The segments are driven directly from port D of the PIC which can drive up to 20mA per bit (although there is a limit of 100mA per port). The digit drive is taken via drive transistors Q2 and Q3.

The 4-button keypad is driven very simply on a 2 by 2 matrix. The PIC selects the columns one at a time, and reads the rows to determine which button is pressed. As port B is used then the built in pull ups on this port are enabled to avoid the need for external pull up resistors. The keypad and display circuit diagram is shown in figure 6.

Serial interface

The serial interface is a very simple and cheap design which has been shown before in previous ETI articles such as the PIC Basic controller and the large matrix display controller. The input is tapped and filtered to provide a negative supply for the output voltage. The performance of this circuit is adequate for any application which does not involve large scale duplex data transfer.

Other features

The control of the speed of the fade or wipe is through a variable resistor on one of the A to D converter inputs of the PIC. This varies between 0V and 5V with a resolution of 8 bits, although the software divides this by 16 to give 16 independent fade speeds. The fastest speed is virtually instantaneous, the slowest is up to around 20 seconds for the fade.

Software operation

It is instructive to consider the operation of the software for this project, which is a mixture of real time control techniques and background operations. In this section some familiarity with the architecture of the PIC 16C74 is assumed, however, understanding it is not necessary to successful construction of the overall project.

The software consists of a main schedule loop, which calls subroutines to perform keypad, display, and fading/wiping processing. The actual switching of video signals is performed on interrupts.

The heart of the control operation is the use of the 8-bit and 16-bit timer/counters in the PIC. The 8 bit timer is TIMER 0, and the 16 bit timer is TIMER 1. TIMER 0 is set to count on an internal clock which is the cycle clock (in this

design the cycle clock is at 1MHz), divided by 128. Therefore the timer increments once every 128us, and overflows every 33ms. TIMER 1 is set to count on each line increment as described in the section above on vertical fading.

The frame valid signal from the sync board is used to cause an interrupt, and this drives the edge triggered interrupt input on bit 0 of Port B. This interrupt is set to trigger on the rising edge of the frame valid signal, and therefore all the processing related to the frame is undertaken at the top of each frame. To guarantee that processing is exactly synchronised to the frame, then the interrupt routine waits for the end of line (using the line valid signal) before performing further processing. This is important to ensure that TIMER 1 is written at the same point in each frame - if not then the vertical wipes will have an unpleasant juddering effect when held stationary.

Interrupt processing is limited to writing the correct value to TIMER 1, switching the video signal on or off, and setting a flag to indicate that a new frame has been processed. After this processing returns to the main loop. The interrupt processor also deals with the serial port using the built in serial hardware of the PIC, the serial port interrupt is only enabled at the top of the frame to avoid any chance of serial interrupts breaking into video switching interrupts.

To enable processing to continue while there is no video signal then the TIMER 0 interrupt is used. If TIMER 0 overflows (when it counts from 255 to 0), it causes an interrupt which is used to set the new frame flag, this will occur every 33ms. However if a video signal is present then the frame interrupt will always occur within 20ms. This is used to reset TIMER0, and it will not overflow. Therefore a TIMER0 interrupt will only ever occur in the absence of a video signal. This is used to set the decimal points on the display as shown in figure 2, and to disable the fader/wiper in the absence of an input signal.

The main loop handles the keypad, display, and calls the routines to deal with the progression of fading and wiping. The display operates on a 4ms multiplexing cycle and is driven from TIMER 0. The multiplexing routine is called every time that there is a change to the top three bits of the timer.

The keypad is read every time that there is a new frame by using the flag set by the interrupt routine. The keypad routines directly call the appropriate action subroutines if a key is pressed.

When a fade or wipe is not under way, the display may be in one of two states, either fully on, or fully off (Channel A selected or Channel B selected). This may be achieved in a number of ways however to ensure that all fades/wipes start from the same condition then the display is set into a known state at the end of any fade/wipe or unfade/wipe. For example, "fully on" has VGAIN set to +5V, SLIDEVOLT set to 0V, SWRISE and SWFALL set to 0 (disabling the outputs of the comparators), SWINVERT set to 1 and SWDIRECT set to high impedance (and therefore pulled high by the PORT B pull-ups on the PIC). Timer 1 interrupts are disabled.

When a fade or unfade starts a routine is called to set the display into an initial state which is the same as the current state, but is ready to undergo the fade or wipe. For example, in the case of a horizontal fade the SWRISE/SWFALL switches must be set together with the correct state on the SWINVERT signal and the correct voltage on SLIDEVOLT.

Through the period of the wipe or fade the voltages on the PWM outputs, or the values pre-loaded into TIMER 1 are changed at the start of the frame, values are changed more rapidly with faster slide speeds.

The fade or wipe routines are called indirectly through a look up table which enables straightforward addition of further routines for additional patterns.

The PIC 16C74

The PIC16C74 is the largest device of the 14 bit series of PIC controllers. It contains 4k of eprom, and is housed in a 40-pin package which allows three 8-bit ports and additional 5-bit and 3-bit ports. The microcontroller has 192 bytes of ram available for use by application programs. The microcontroller holds a large number of peripheral devices detailed below. Despite the size and versatility of the device it is reasonably cheap, and is a very cost effective embedded control solution.

The device contains an asynchronous serial interface and baud rate generator. The serial interface is interrupt driven. Unlike a software implementation the asynchronous interface operates during program running, and caches up to three received bytes before they may be read by an interrupt service routine (ISR). The transmitting routine holds a byte currently in transmission together with a cache register which holds the next byte to be transmitted, this allows continuous transmission at the current baud rate without interruption for the ISR to write the next byte.

The 16C74 has three timers and a capture compare register. The first timer is an 8-bit timer which causes an interrupt on overflow. In this project the timer is used for display multiplexing and provides a replacement for the frame interrupt in the absence of a video signal. The second 16-bit timer (TIMER 1) is used to count lines within the frame, the second timer provides 16-bit resolution. The third timer is 8-bit, and has a preset register which may be used for providing any output frequency in the timer range, which is used for the PWM outputs. The capture/compare register is used for capturing the time of events.

In common with all the devices in the 16C7X range the 16C74 contains an A/D converter. This is switched by an 8-way multiplexer to up to 8-analogue input ports, the reference voltage is selectable internally, or again from an external source. The A/D converter contains an internal sample/hold circuit and has a maximum conversion frequency of 50kHz for 8-bit resolution.

The 16C74 runs the standard PIC assembly language, and can be programmed serially both out of circuit and in-circuit by most PIC programmers.

Next month

In next month's article, which completes the fader/mixer, we will look in further detail at the setting of the various signals in the circuit to achieve each of the fade and wipe patterns. We will also look at changes required to provide additional patterns, and the detailed electronic and mechanical construction of the project. We will also look at providing PC control of the mixer for programmed effects.

Centronics Mini-Lab data logger/controller

A universal solution to allow your computer to collect data and control electrical systems. By Dr. Pei An

A data logger or a data acquisition system is a device that enables a computer to read analogue signals such as temperature, pressure, light intensity, sound level, etc. in the external world into the 'computer world'. A computer can also control hardware events in the external world using its digital outputs. Utilising proper drivers, things like lights, motors, stepper motors, heaters, etc. can be controlled. Clearly, if a computer not only reads information but also exerts control, it could form a powerful closed-loop system and can be used for virtually any applications.

With increasing use of laptop and palmtop computers, the traditional 'plug-in' card approach is no longer the universal solution for computer hardware expansion. One function that is common to all types of computers is their parallel port (Centronics port). The mini-lab data logger/controller utilises this port. It is in the form of an external device and is connected to the Centronics port via a standard printer cable.

The Mini-lab data logger/controller offers eight analog inputs with an 8-bit A/D conversion accuracy (this can be converted to achieve 10-bit accuracy). The input voltages are uni-polar and the range is 0-5V. The maximum data conversion rate could be several kilohertz. It also provides one digital input and five digital outputs. The digital I/O lines can be used for high-speed serial data transfer applications and the output lines for external control. The device is powered either by an on-board PP3 9V batteries or by an external 8-15V power supply and it consumes 12 mA current. It is housed in a slim size box (60 mm wide 100 mm long and 20 mm high).

For easy wiring, detachable screw connector blocks are used. Because of its low power consumption and small size, it

is ideal to work with laptop or palmtop computers for portable data acquisition and close-loop control applications. It can be used in home automation, in research laboratories and in industries. For experimenters, they can use this data logger as a basic equipment for various computer interfacing experiments. Figure 1 shows the complete system, together with pin functions of the connector blocks.

The data logger/controller is built on a single-sided PCB board. A designer's kit is available from the author (see details at the end of this article).

The A-to-D converter

The circuit diagram is given in figure 2. The A/D converter (TLC540 or TLC541, IC1) is an 11-channel serial I/O converter (for the pin layout see figure 3). The converter requires an external SYSTEM CLOCK input. Its serial I/O interface requires three inputs (I/O CLK, -CS and ADD) and one output (DATA OUT). They are used for selecting a multiplexed analogue channel, controlling a-to-d conversion and transferring the converted data. In this application, I/O CLK, -CS and ADD are connected to three lines of the DATA port of the Centronics interface (I/O CLK-DB0, -CS-DB2 and ADD-DB1). DATA OUT is connected to DB3 of the STATUS port. The operation of the A/D converter and the Centronics interface are described later. The converter provides 11 analogue inputs, however, the data logger only uses eight inputs (AN0 to AN7). Each input is protected by a voltage limiting zener diode in case of accidental connection of high voltage or reversed polarity to the input. Another analogue input (AN10) is used by the data logger itself to monitor the supply voltage of the battery.

In figure 2 it can be seen that the +5V power is divided by R16 and R17 and then is fed into AN10. This is one of the self-diagnostic features of the data logger. The eleventh analogue input (AN11) is connected to an internal voltage reference inside the A/D converter. The conversion result should be a value of between 125 and 131. Again, this is for self-diagnostic purposes.

The SYS CLOCK is generated by a COMS 7555 timer (IC3). It is configured as an equal mark-to-space ratio astable. R14 and C1 determine the oscillation frequency. In the present case, the frequency is about 1.2 MHz. The voltage reference required by the converter is produced by a TLE2425CLP precision voltage reference, which gives a voltage reference of 2V5 \pm 0.8 percent. Consequently, the analogue voltage range is 0 to 5V.

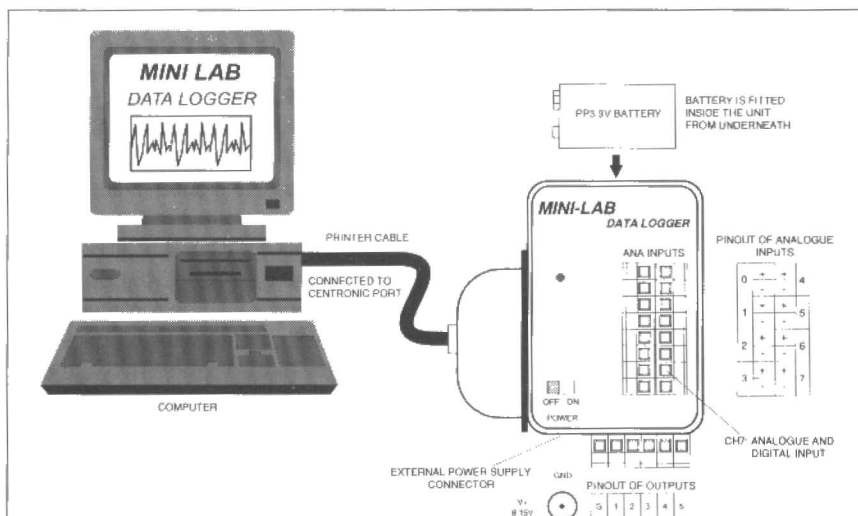
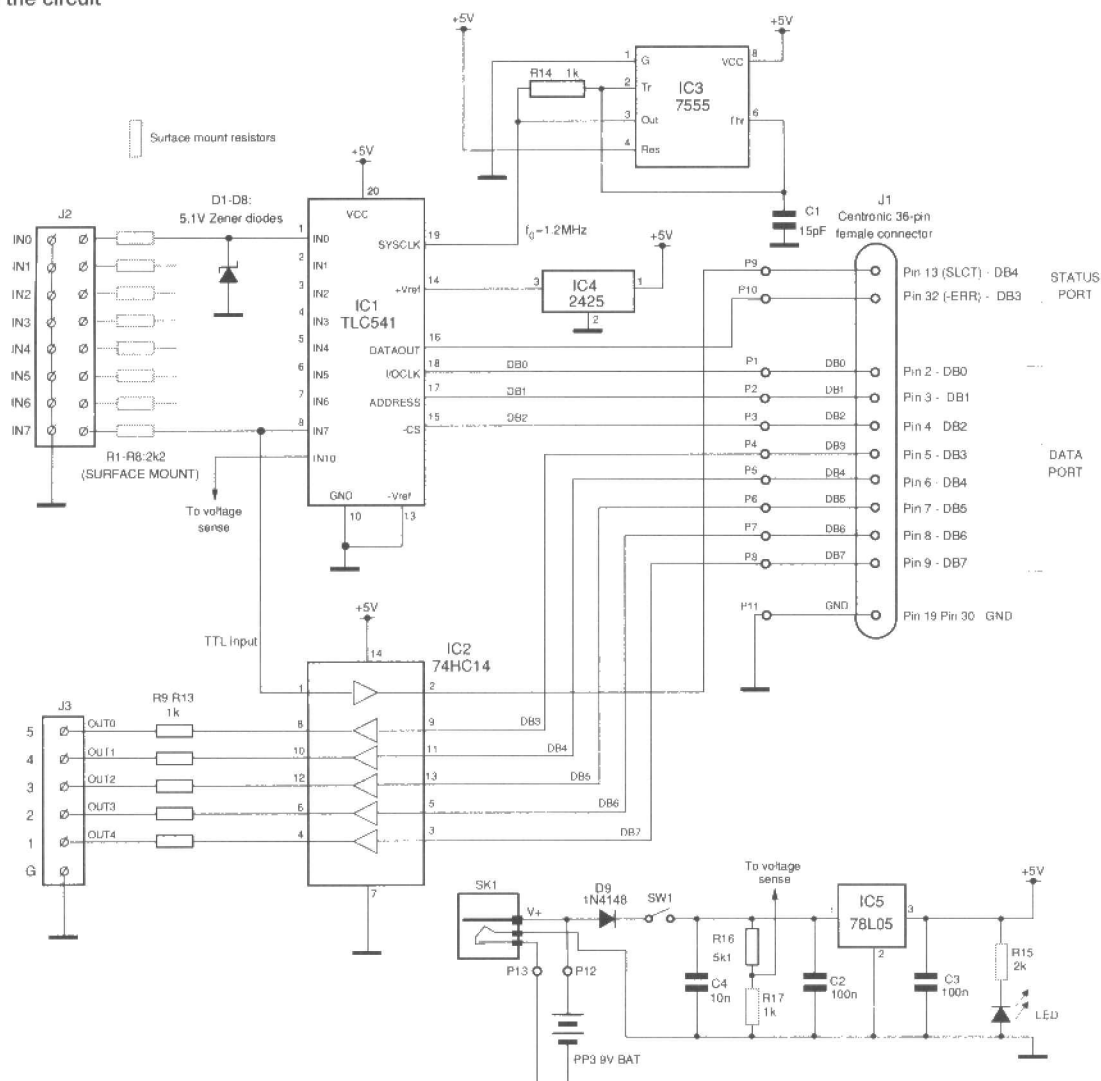


Figure 1: the Mini-lab data logger/controller system

Figure 2: the circuit



Digital I/Os

The eighth analogue input is also used as a one-bit digital input, if its voltage level satisfies TTL voltage requirements. The line is buffered by IC2 (a 74HC14) and is connected to DB4 of the STATUS port. The five digital outputs are connected to five lines of the DATA port of the Centronics interface (DB3 to DB7) via buffers, IC2.

The power supply

The data logger is powered either by a PP3 9V battery or by an external power supply (8-15V DC). An on-board 100mA +5V regulator (IC4) is used to convert the power supply into +5V. The external power is plugged into the power socket (SK1). When the external power is used, the on-board battery is automatically disconnected. An ON/OFF switch (SW1) is provided to switch on or off the power.

TLC540/541 A/D converter

The TLC540/TLC541 A/D converter is a linear CMOS 8-bit successive-approximation A/D converter. It has an on-board sample-and-hold circuit, a 12-channel analogue multiplexer and a serial I/O interface which enables it to perform simultaneous read and write operations. The TLC540 is able to sample 75,180 times per second and TLC541, 40,000 samples per second. These converters can be replaced by TLC1540/TLC1541 converters, which have a 10-bit conversion accuracy and are fully compatible to the former. They are able to sample 32,258 times per second.

The pin-out of the IC has already been shown in figure 3. Pin 20 (VCC) and Pin 10 (GND) are connected to the positive and negative rails of the power supply. The range of the power supply voltage is between 4V75 to 6V5, with a typical power dissipation of 6 mW. Pins 14 and 13 (REF+ and REF-) are

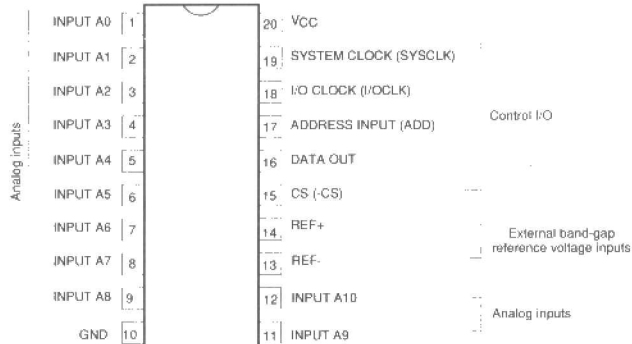


Figure 3: pin-out of the TLC540 and TLC541 8-bit A/D converter and TLC1540/TLC1541 10-bit A/D converters

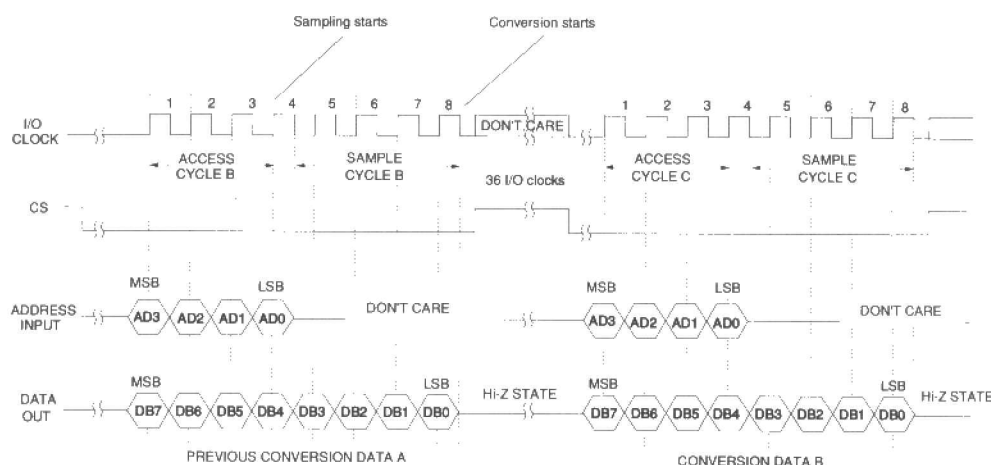


Figure 4: the operation sequence of the TLC540/541 serial A/D converter

connected to an external band-gap voltage reference. REF- and ground (Pin 10) are normally wired together.

Amongst the 12 analogue multiplexers, the first 11 inputs could be accessed at Pins 1 to 9, 11 and 12, corresponding to analogue inputs from 0 to 11. The other input is connected internally to a 'self test' voltage reference. To select a particular analogue input, a 4-bit address should be written into the IC via the serial interface.

The serial interface consists of five TTL-compatible 3-state I/O lines, namely, the System Clock input (SYS CK, Pin 19), the I/O Clock input (I/O CK, Pin 18), Chip Select input (-CS, Pin 15), Address Input (ADD IN, Pin 17) and Data Output (DATA OUT, Pin 14). The SYS CK is the clock for data conversion operation. A maximum 4-MHz system clock could be applied for TLC540 and 2.1 MHz for TLC541, giving 75,180 and 40,000 samples per second respectively. For TLC1540/TLC1541 the maximum system clock is 2.1 MHz, giving 32,258 samples per second. The I/O CLK is for synchronising I/O operations. ADD IN is the serial address input for selecting the analogue multiplexers. DATA OUT is the serial data output. -CS is the chip enable. It must be at logic low to enable the IC. When -CS is high, the DATA OUT pin is three-state. The ADD IN and I/O CLK are all disabled. This allows several such devices to be used in a shared bus.

The SYSTEM and I/O CLK are used independently and do not require special speed or phase relationships between them. This simplifies the interfacing requirements. Once a clock within the specified frequency range is applied to the SYSTEM CLK, the control hardware and software need only to be concerned with addressing the desired analogue channel, reading the conversion result and starting the conversion by using the I/O CLK. The writing and reading sequences of the IC are explained as follows (see figure 4).

1. -CS goes low to start read/write cycle. To minimise errors caused by noise at the -CS input, the internal circuitry waits for two rising edges and then a falling edge of the SYSTEM CLK after the high-to-low transition is detected on the CS pin, before it is accepted. The MSB of the previous conversion result (DB7) automatically appears on the DATA OUT pin.
2. A new multiplexer address (AD0, AD1, AD2 and AD3) is shifted into the IC on the first four rising edges of the I/O CLK. The MSB of the address (AD3) is shifted in first. The negative edges of the I/O CLK shift out DB6, DB5, DB4 and DB3 of the previous conversion result. The on-chip sample-and-hold begins sampling the newly addressed analog input after the fourth falling edge of the I/O CLK.
3. Three clock cycles are further applied to the I/O CLK. DB2, DB1 and DB0 of the previous conversion result are shifted out on each negative edge of the I/O CLK.
4. The final (8th) clock cycle is applied to the I/O CLK. The falling edge of the clock completes the sample process and initiates the hold function. Data conversion is then carried

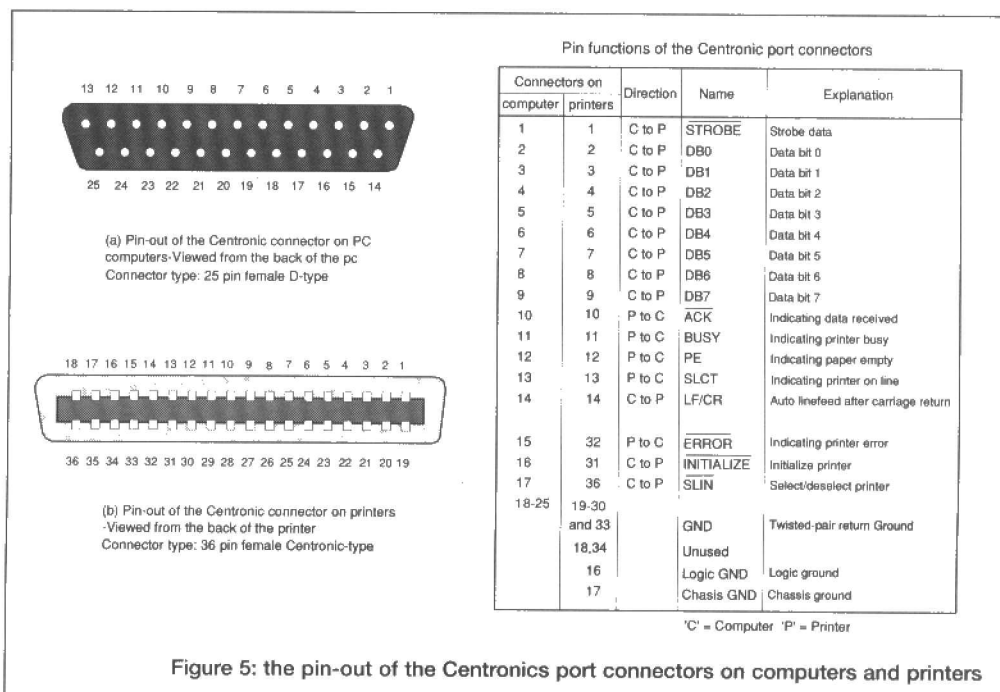


Figure 5: the pin-out of the Centronics port connectors on computers and printers

out during the next 36 SYSTEM CLK cycles. After this I/O CLK, either -CS must go high or the I/O CLK remains low for at least 36 SYSTEM CLK cycles to allow for the data conversion. -CS can be kept low during periods of multiple conversion. However special care must be exercised to prevent noise from getting into the I/O CLK, which otherwise will cause the device and the external interface circuit to loss synchronisation. If -CS is taken high, it must remain high until the end of the conversion. A valid falling edge of -CS will cause the device to reset and to abort the conversion in progress.

The Centronics interface

The Centronic interface, which is also referred to as the printer port or the parallel port, is an industrial standard interface designed originally for interfacing with printers. A PC, no matter whether it is a desktop or a laptop, has at least one such interface installed. Three more printer ports may be added to the PC using external cards (for desktop computer only). These ports are given the logical names LPT1 to LPT4.

The connector on the computer side and on the printer side are different (see figure 5). The one on the computer is a 25 pin D-type female connector (see figure 5a) and the latter is a 36-pin female Centronics-type connector (figure 5b). To connect the computer and the printer together, a cable, known as the printer lead, is used. Although the two connectors are different, their functions are the same. The pin-out of the connectors and the functions are summarised in figure 5.

Table 3: Base Addresses for LPT1 and LPT2 printer port

	Base Address
LPT1, with mono card	956D, (3BCH)
LPT1, with I/O card	888D, (378H)
LPT2, I/O card	632D, (278H)

The I/O lines in the Centronics port are organised into three groups. They are named the DATA, CONTROL and STATUS group. The functions of these group are discussed as follows:

DATA GROUP:

This sends data from the PC to the printer. It has eight latched lines (DB0 through to DB7) and is controlled by an I/O port of the microprocessor inside the PC.

CONTROL GROUP:

This controls the operation of the printer. It contains four latched lines (-STROBE, -LF/CR, -SLIN and -INITIALIZE) which are directed from the PC to the printer. The group is controlled by an output port of the CPU. Note that -STROBE, -LF/CR AND -SLIN lines are inverted and -INITIALIZE is not.

STATUS GROUP:

This group is used by the PC to obtain current status of the printer. It contains five lines (-ERROR, SLCT, PE, -ACK and BUSY), which are directed from the printer to the computer. It is controlled by an input port of the CPU. BUSY line is inverted and the other four lines are not inverted.

As mentioned above, the three groups are controlled by three I/O ports of the microprocessor inside the PC. The corresponding ports are also named the DATA, CONTROL and STATUS port. Their bit functions are given in Table 1.

I/O addresses of ports

The CPU addresses of the DATA, CONTROL and STATUS ports can be calculated using the expressions in Table 2.

It can be seen that the printer address is the same as the address of the data port. The base addresses for LPT1 and LPT2 are listed in table 3. The address values are in decimal and values in brackets are in hex.

Table 1: Bit functions of the input/output ports of the Centronics port

Bit	Centronics port	Functions name
Data port		
bit 0-7	DB0 - DB7	data from bit 0 to bit 7
Control port		
bit 0	-STROBE	LOW=normal; HIGH=output of data
bit 1	-LF/CR	LOW=normal; HIGH=auto line feed after carriage return
bit 2	-INITIALIZE	LOW=initialize printer; HIGH=normal
bit 3	-SLIN	LOW=deselect printer; HIGH=Select printer
bit 4		LOW=printer interrupt disabled; HIGH=enabled
bit 5-7		Unused
Status port		
bit 0-2	UNUSED	Unused
bit 3	-ERROR	LOW=printer error; HIGH=no error
bit 4	SLCT	LOW=printer not on-line; HIGH=printer on-line
bit 5	PE	LOW=printer has paper; HIGH=out of paper
bit 6	-ACK	LOW=printer acknowledges data sent; HIGH=normal
bit 7	BUSY	LOW=printer busy;

Table 2: I/O Addresses of the DATA, CONTROL and STATUS port

CPU I/O address	DATA PORT (PC to PRN)	CONTROL PORT (PC to PRN)	STATUS PORT (PRN to PC)
LPT1 to LPT4	Base address	Base address+2	Base address+1

It can be seen that the base address for LPT1 varies. This depends on the hardware configuration of the PC. The parallel port that comes with the monochrome display adaptor card has a base address of 956 decimal and that comes with an I/O expansion board has an address of 888 decimal.

Knowing the base address of the printer port of a PC, the addresses of the CONTROL and STATUS port can be calculated (see table 2). There are two ways to obtain this address. One is to check the user's manuals of your computer or to watch the screen carefully after the computer is powered on or reset. A table showing all the hardware specifications will appear on the screen. The other way is a convenient one. When the computer is powered on or reset, the BIOS (Basic Input Output System) checks all the possible printer addresses. If it finds an installed Centronics port, it writes the addresses of the ports to a special memory location. For LPT1, this address (a 2-byte word) is stored at 0000:0408 and 000:0409 (in hex). By peeking this memory location, the base address can be obtained. The memory locations for LPT1 to LPT4 are listed in below.

LPT	Memory address
LPT1	0000:0408 - 0000:0409
LPT2	0000:040A - 0000:040B
LPT3	0000:040C - 0000:040D
LPT4	0000:040E - 0000:040F

This is another useful one-byte memory location, 000:4011. It stores the total number of installed Centronics interfaces. It is noted that this information is contained in DB6 and DB7.

DB7	DB6	Number of Centronics ports installed
0	0	0
0	1	1
1	0	2
1	1	3

The following procedure (in Turbo Pascal 6) detects the number of centronic interfaces installed and assign the number to a variable Number_of_LPT. Then it reads the address from the memory location holding the base address of LPT1 and assign the value to a variable: P_address.

```

Procedure Input_printer_address;
{Find the printer address of LPT1 and print out the result;}
var
  P_address1, Number_of_LPT:integer;
begin
  Number_of_LPT:=mem[$0000:$0411]; {read a byte from a specified memory location}
  P_address1:=memw[$0000:$0408];{read a word from a specified memory location}
  writeln('Total number of installed Centronics interface: ', Number_of_LPT:2);
  writeln('LPT1 address -',P_address1:3,' was detected on your PC');
end;
```

Software control of ports

There are three methods to control the Centronics port.

1): Using printer operation procedures

This method uses instructions which control printer operation. For example, in BASIC, this instruction is "PRINT". In Turbo

Pascal, it is "WRITELN(LST)". When executing such instructions, the DATA, CONTROL and STATUS groups operate together and can not be used individually. This method is only useful for printer operations. For general purpose I/O interfacing applications, it is not recommended because of the lack of flexibility.

2): Using BIOS interrupt

Another method uses BIOS interrupt INT 17h. It is also used for printer operations. Some of the lines in DATA, CONTROL and STATUS groups are used together.

3): Using direct I/O access

This method controls the DATA, CONTROL and STATUS ports separately using direct I/O access instructions. In this case, the Centronics port is treated as three separate I/O ports (forget the pin functions!): two of which are output ports and one of which is an input port. Let us take an example of controlling LPT1. Assuming that the addresses of the DATA, CONTROL and STATUS ports are 888D, 890D and 889D, respectively, to send data to the DATA and the CONTROL ports, the following procedures are used:

In BASIC OUT 888, x and OUT 890, x
In Turbo Pascal PORT[888]:=x and PORT[890]:=x

in which x is the output value in decimal. To read data from the STATUS port, the following procedures are used.

In BASIC, Y=INP[889]
In Turbo Pascal Y:=PORT[889]

in which Y is the decimal value of the input data.

Referring to figure 3, it should be noted that when writing data to the CONTROL port, the 4 output lines corresponds to bits 0 to 3 of port 890D and DB0, DB1 and DB3 are inverted. When reading data from the STATUS port, the 5 input lines correspond to bits 3 to 7 of the port 889D and DB7 is inverted. As a result, bit modification has to be performed for the data to be sent to the CONTROL port and the data received from the STATUS port. The following two examples show how to do this.

Example 1

In an application, all the lines in the CONTROL port are required to output '1' at the same time. When using a Turbo Pascal command PORT[890]:=x, what is the value x.

Solution

DB0=0, DB1=0, DB2=1, DB3=0. x is equal to 4. you may see that DB0, DB1, DB3 are all 0. However, after being inverted the output values from the Centronics connector are all 1.

Example 2

In an application, a four-bit data from DB0 to DB3 are connected to BIT 3 through to BIT 6 of the STATUS port. When using a Turbo Pascal command Y:=PORT[889], how to obtain the value of the 4-bit data.

Solution

Step 1 executing 'Y1:=PORT[889]' inputs the 4-bit data. The binary format from MSB to LSB of Y1 is X3210XXB. 'Xs' are the bit values which are not useful. '3 2 1 0' are the bit values of DB0 to DB3 of the input 4-bit data. The following procedure is to convert X3210XXB to 00003210B.

Step 3 executing 'Y3:=Y2 SHR 3' (bitwise shift right 3 bits) converts Y2 (03210000B) into Y3 (0003210). Hence Y3 is equal to 00003210B which has the same value as the input data.

The data logger is constructed on a single-sided PCB board. The component layout is given in figure 6. Some surface mount

resistors are used and they should be soldered on the track side of the PCB board. The ics 1 to 3 are static sensitive devices and ic sockets should be used. The wiring between the PCB board and the Centronics connector is given in figure 6. J2 and J3 have two parts, the pcb mounting pin header and screw block. The former is soldered onto the pcb board and the latter is inserted into the pin header after the data logger is assembled. There is no adjustment needed, once it is properly assembled, it should work straight away.

The assembled pcb board is housed in a slim size plastic box. The cutting details of the box is given in figure 7. The photo shows the assembled data logger.

36-WAY FEMALE CENTRONIC CONNECTOR

SURFACE MOUNTING RESISTORS

MINI-LAB DATA LOGGER

PIN19

PIN32

PIN2

PIN3

PIN4

PIN5

PIN6

PIN7

PIN8

PIN9

PIN19

PIN32

ON-BOARD 9V BATTERY

V+

8-15V

GND

DIGITAL OUTPUTS

ANALOGUE INPUTS

PINOUT OF ANALOGUE INPUTS

0	++	4
1	--	5
2	++	6
3	--	7

Applications

Analogue inputs

The data logger has been designed with a view to doing various tasks. The eight analogue inputs, needless to say, are used for measuring analogue voltage signals. The signals can be from various sensors for measuring temperature, pressure, pH, light intensity, sound intensity, magnetic intensity, fluid flow, position, speed, rotational speed, acceleration, bio-electro signals such as ECG (electrocardiograph), seismic-electro signals ... to give some examples.

Digital I/Os

The eighth analogue input is also a TTL input, if the input signal satisfies the TTL voltage level requirement. There are also five TTL outputs. These digital input and outputs exhibit a high data transfer rate, and can be used for various applications. Some applications are:

Voltage-to-frequency converters: V/F converters can be connected to the digital input. The frequency of the signal produced by the converter is measured by the computer and from this the input voltage can be calculated. One feature of such a system is that only one digital line is required.

Light-to-frequency converter: The converter converts light intensity incident on the light sensitive area of the component into frequency, and is a good solution for light intensity measurement. It can be connected to the data logger via one digital line.

Serial I/O temperature sensors: Such sensors convert temperature into frequency.

Serial I/O D/A and A/D converters: Using serial D/A converters allows the Mini-lab data logger/controller to output analogue signals as well.

I2C and RS232: One input and one output line can form an I2C bus. This opens the possibility of utilising all the I2C family components such as DTMF generators, real time clocks, eeproms, I/O expansion ics, etc.

Other serial communication systems: Encoder/decoder communication system can be achieved. Serial radio, infra-red, fibre optic and ultrasonic links can be implemented.

Digital outputs

The digital outputs find a wide range of applications for external hardware control. By using serial loading driver chips, the five outputs can be expanded up to 16 outputs. They can be used to control light emitting and laser diodes, various light bulbs, AC, DC and stepper motors, heaters, speakers, for example.

Application examples

Figure 8 shows how it is used for controlling temperature of a room. Temperature signals from sensors 1 to 3 are fed into the analogue inputs of the data logger. One output controls the on/off of electric heaters. A computer program is required for such an application. A temperature sensor circuit is given in figure 12a using a LM35 temperature sensor. It requires a power supply from 4 V to 20 V and

Figure 8: a temperature control system using the Mini-lab data logger

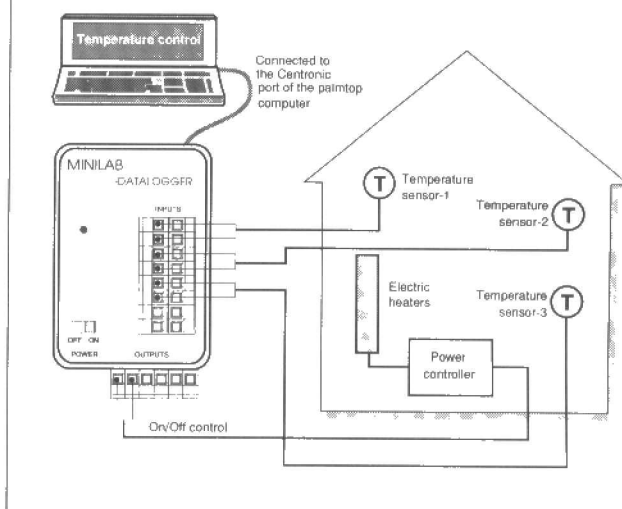


Figure 9: a water level control system using the Mini-lab data logger

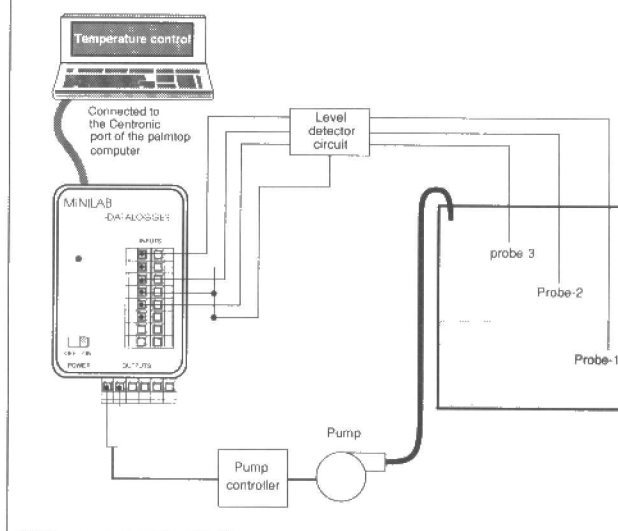
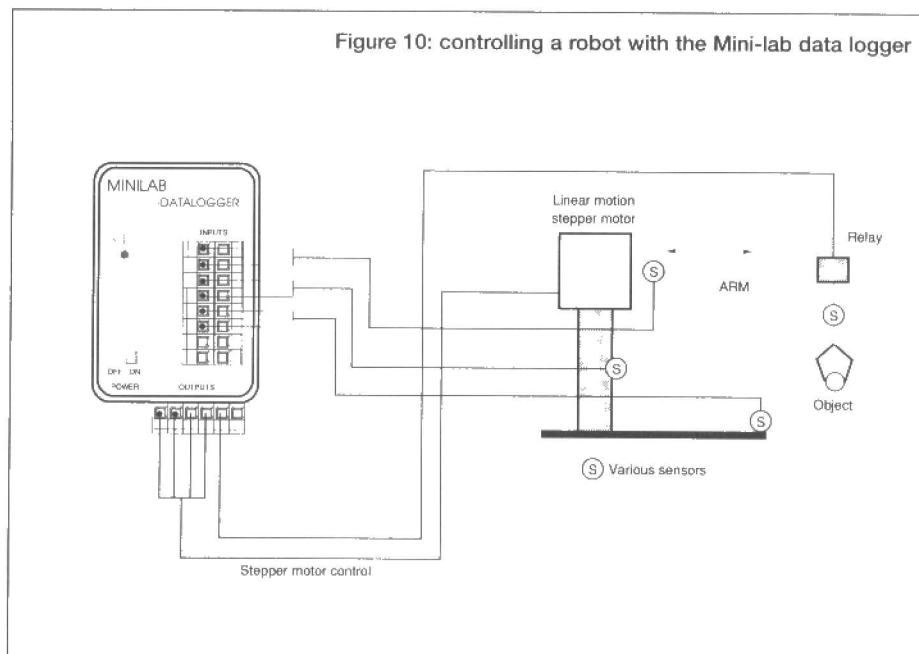


Figure 10: controlling a robot with the Mini-lab data logger



gives 0 mV when the temperature is zero degree C. For every degree increased, the output voltage increases by 10 mV. Because the data logger has 8-bit conversion accuracy, the smallest detectable voltage step is the reference voltage 2V5 divided by 256, giving 9mV77. Therefore, the smallest detectable temperature is about 1 degree C. The digital output from the data logger can not provide enough power to drive any loads. Proper drivers should be used. Figure 11a shows how relays are used to control high voltage and high power devices such as heaters. High power transistor, triacs or solid state relays can be used as well. If the data logger is to be used for controlling mains operating devices, it must be electrically isolated from the high voltage side. Opto-isolators or solid state relays can be used for this purpose.

Figure 9 illustrates an example of controlling the water level in a tank. Several water contact probes are installed inside the tank. The signals from the probes are fed into the analogue inputs of the data logger and one of the outputs is used for

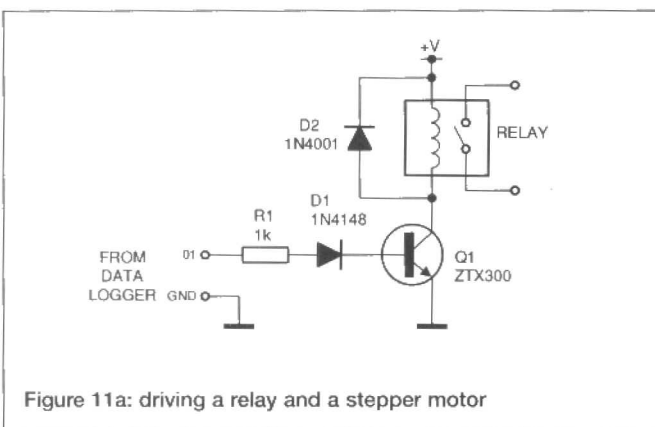


Figure 11a: driving a relay and a stepper motor

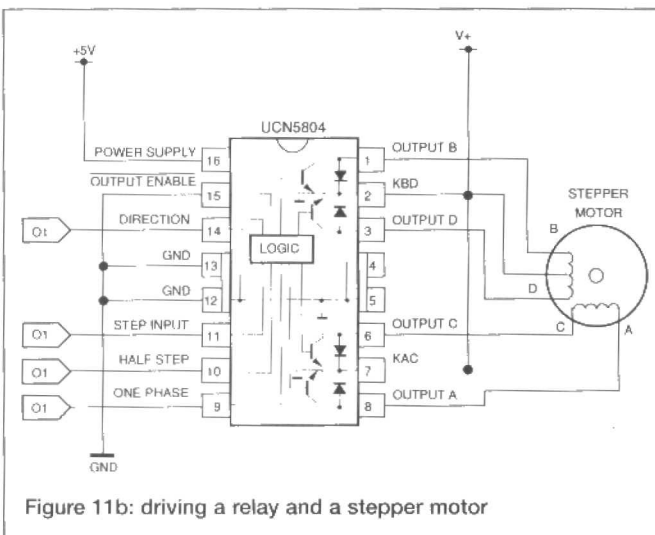


Figure 11b: driving a relay and a stepper motor

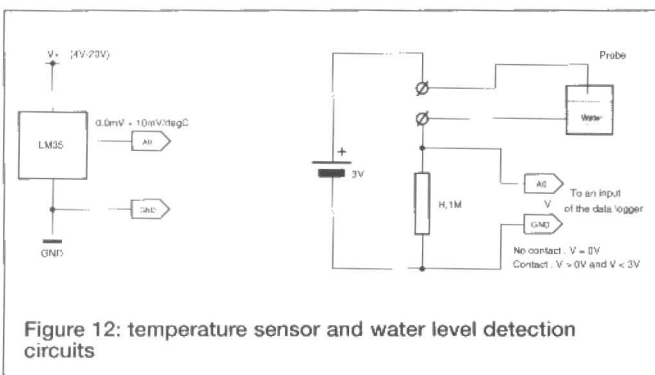


Figure 12: temperature sensor and water level detection circuits

controlling a water feed pump. Again, a computer program is need for this application. The circuit for the water level probe is given in figure 12b. A relay circuit shown in figure 11a can be used for controlling the pump.

Figure 10 shows how the data logger can be used for robotics applications. Signals from various sensors (S) are fed into the data logger. Three digital outputs are used to control a linear motion stepper motor and another output controls a relay. Figure 11b shows a stepper motor driver using an UCN5804 IC.

Technical support

The complete kits including all the components, casing and software in TP6 source code and EXE file are available from the author at a price of £46 plus £3 P&P (£5 outside the UK). The software on disk alone is £12.50 inclusive of P&P. Please direct your enquiry to Dr. Pei An, 11 (Plot 118) Sandpiper Drive, Stockport, Manchester, SK3 8UL. U.K. Tel/Fax: +44-(0)161-477-9583, E-mail: PAN@FS1.ENG.MAN.AC.UK.

ETI will publish the software listing (about 750 lines) in the next issue if there is demand for a printed source.

PARTS LIST For the Mini Centronics Data Lab

Resistors

R1-R8	2.2k surface mount
R9-R14	1k 0.25W 1% metal film
R15	2k 0.25W 1% metal film
R16	5k1 0.25W 1% metal film
R17	1k surface mount

Capacitors

C1	15pF ceramic disc
C2,C3	100nF ceramic disc
C4	10uF capacitor

Semiconductors

IC1	TLC541 8-bit, 12 channel serial A/D converter
IC2	74HC14 Schmitt trigger
IC3	7555 timer
IC4	TLE2425 2.5V voltage reference
IC5	78L05 +5V 100mA voltage regulator
D1-D8	5.1V zener diode
D9	1N4148
LED	3 mm low current LED

Miscellaneous

J1	Centronic female 36-pin connector
J2	Two 8-way PCB connectors with screw terminals
J3	6-way PCB connectors with screw terminals
SW1	PCB mounting SPDT switch
SK1	2.5mm PCB mounting power connector
BAT	9V PP3 battery
PCB	
Case	Slim size ABS case
No.4 6.4 mm self tapping screw	2 off
2BA screws	6 off
2BA pillar	3 off
2BA plastic washer	3 off
wires	(Not included in kit.)

New Lamps for Old

Terry Balbirnie shows how to change a nickel cadmium torch into a lead acid rechargeable torch and improve battery life.

This article describes how to convert a hand lamp that normally uses throw-away batteries to work with rechargeable ones. Since the price of replacement batteries (about £6) may actually be more than the cost of the lamp itself, this conversion will soon pay for itself in terms of savings. It will also ensure that the lamp operates at peak brightness.

The lamp should be one that uses four "D" size cells in a square side-by-side arrangement - that is, not stacked. The work involves fitting replacement batteries and constructing a separate mains-operated charging unit. The lamp will be fitted with a fuse and a socket on the side, and the bulb will also be replaced with one of a different voltage rating.

This is a Mains project and is not advised for constructors without mains experience.

Lack of energy

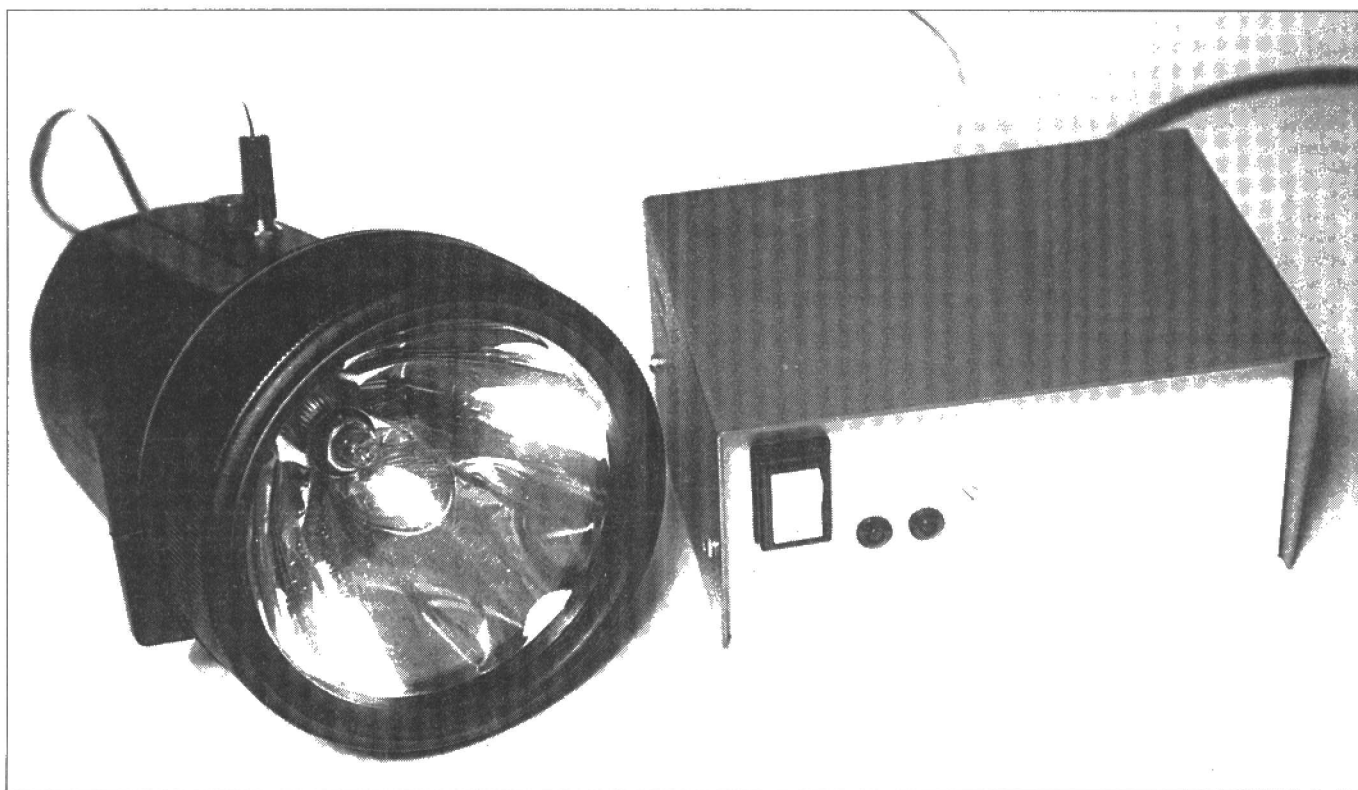
Commercial rechargeable lamps are generally powered by nickel-cadmium batteries. However, although popular, these are not well suited to the purpose. They perform best when substantially discharged before recharging, but this does not suit hand-lamp use. Operating it in the normal way, for relatively short periods of time, only partially discharges the batteries, and they will tend to develop a memory effect and fail to accept a full charge. Ni-cad cells also self-discharge rather rapidly, which means that if the lamp is left unused for only a month or two, it would lose a large proportion of its energy.

Heavy-duty industrial hand lamps sometimes use sealed lead acid batteries. This project is based on that principle. This type of battery keeps its charge for longer than ni-cads. It accepts a slow continuous charge better, if required, and does not suffer from memory effect. Some care must be taken to avoid discharging these cells too deeply but, if this precaution is observed, they will provide years of reliable service.

The capacity of the specified lead acid cells is 2.5Ah, compared with the original throw-away alkaline ones quoted at 12.5Ah. This would make the capacity of the rechargeable battery 5 times lower. This is not actually the case, since the capacity of an alkaline cell is stated for discharge from a nominal 1.5V to only 0.9V. Thus, the four cells would provide only 3.6V at the end point and would therefore give a very poor light. In practice, they would have been discarded long before. It is probably true to say that the lead acid cells will operate the lamp for about one-third the period of the alkaline ones. The converted lamp will operate the specified bulb at full power for about 3 hours, which will be sufficient for most purposes.

I'm on charge

Lead acid batteries must be charged from a carefully controlled supply. Haphazard treatment will result in permanent damage. In practice, charging is usually carried out from a constant voltage source. The nominal terminal voltage of a single cell is 2 volts, although it varies slightly with the state of charge. A supply voltage of 2V3 to 2V4 per cell may be used for continuous connection (sometimes called trickle, standby or



float charging). To charge the cell more quickly after a substantial discharge (cyclic charging), the supply voltage may be raised to between 2V4 and 2V55. In this circuit, either cyclic or trickle charging may be selected by means of a switch on the unit.

The difference between the supply and battery voltage is available to drive current through the cells and charge them. Even a small voltage difference will result in a relatively large current, due to the very small internal resistance of this type of battery. A lead acid cell may be regarded as discharged when its terminal voltage falls below 1V95. When it is connected to the charger, there will be an excess voltage of about 0V4 (trickle mode) or 0V5 (cyclic mode) and the current will be relatively high. To prevent damage to the cell, or to components in the charging circuit, it will be necessary to limit this current to a safe value. As the cell charges, its terminal voltage will rise and the excess voltage fall to the point where only a small current flows. In the case of trickle charging, this will be less than 5mA and will simply make up for losses and maintain the charge. If the higher (cyclic) voltage is used, the end-point current will be greater (in the prototype unit it was 7mA). For this reason, the battery should not be connected continuously in cyclic mode, since maintaining a current greater than 5mA could reduce its life.

How it works

The circuit diagram of the charger unit is shown in figure 1. Transformer T1 reduces the 230V mains supply to a nominal 9V ac at each secondary winding. These are wired in series with the common connection (centre tap) forming the 0V line (negative output). The supply is full-wave rectified using the conventional arrangement of diodes, D1 and D2, smoothed by capacitor C1. The result is then regulated to the voltages appropriate to trickle or cyclic charging by IC1 and its associated components.

Regulator IC1 accepts the basic input at pin 1 and provides an output at pin 5. Capacitors C2 and C3 are necessary for the stability of the ic. The output current flows through resistor R1, developing a small voltage across it. This is sensed by the limiting input pin 2 and, when it rises marginally above 0V45, the current is automatically reduced by on-chip circuitry to maintain this value. This is the current-limiting aspect mentioned earlier. With R1 as specified, and taking into account stray resistance in the circuit, the maximum output current will be 800mA approximately.

The voltage appearing at the charger output is related to the resistance between IC1 pins 2 and 4 on one hand and that between pin 4 and ground (fixed at 820 ohms) on the other. With switch SW1 open, the resistance between pins 2

and 4 is simply that of preset potentiometer (connected as a variable resistor) RV1 in series with fixed resistor R3. With switch SW1 closed, pole A connects a further preset, RV2, in parallel with RV1 and this has the effect of lowering the overall value. The output voltage is then reduced. The presets will be accurately adjusted to provide the voltages appropriate to cyclic and trickle charging at the end of construction.

The other pole of SW1 (pole B) operates the flashing red light-emitting diode, LED1, when set to cyclic and the green one, LED2, when in trickle mode. Note that the specified LEDs do not need a series resistor. If these LEDs are not available, standard ones could be used instead, but a 220 ohm series resistor would be needed. Fuse FS1 provides protection to the primary (mains) section of the circuit. Due to the electronic current limiting, there is no need for a fuse in the output circuit, although there will be one in the lamp itself.

Construction

Do not use a plastic case for this circuit - a metal enclosure is essential to act as a heat sink for IC1. Note also that the case must be earthed and the correct fuse used as described.

The PCB component layout is shown in figure 2. Transformer T1 is heavy and needs the support of four fixings. These will also support the PCB inside the case. The large copper land area on the underside of the board provides firm anchorage for the component pins, plus additional support.

Solder the transformer, fuseholder and terminal blocks for input (TB1) and output (TB2) leads in position. Then do the other components, except IC1, checking the orientation of D1, D2, C1 and the polarity of the LEDs - the slightly shorter lead is the negative one. R1, specified at 0R56, is shown as a single unit in figure 1, but will probably be two 1 ohm resistors in parallel, providing 0R5, because it can be difficult to get a single low-power resistor of less than 1 ohm. Both are labelled "R1" in figure 2. If used, a single 0R56 resistor would occupy either "R1" position in figure 2. A suitable power rating would be 0.5W or 0.6W.

Note that IC1 is available in two forms, a 4-lead TO3 case and a "Pentawatt" package. Only the Pentawatt type is suitable here. Spread its pins slightly so that they correspond with the holes in the PCB and solder the ic with the metal backing facing the edge of the PCB. Adjust RV1 and RV2 sliding contacts to approximately mid-track position. Solder 10-cm pieces of light-duty stranded connecting wire to the pads labelled "SW1a trickle" and "SW1a common", and other pieces to the pads labelled "SW1b trickle", "SW1b cyclic", and "SW1b common". Use different colours of wire to help avoid incorrect connections to the switch.

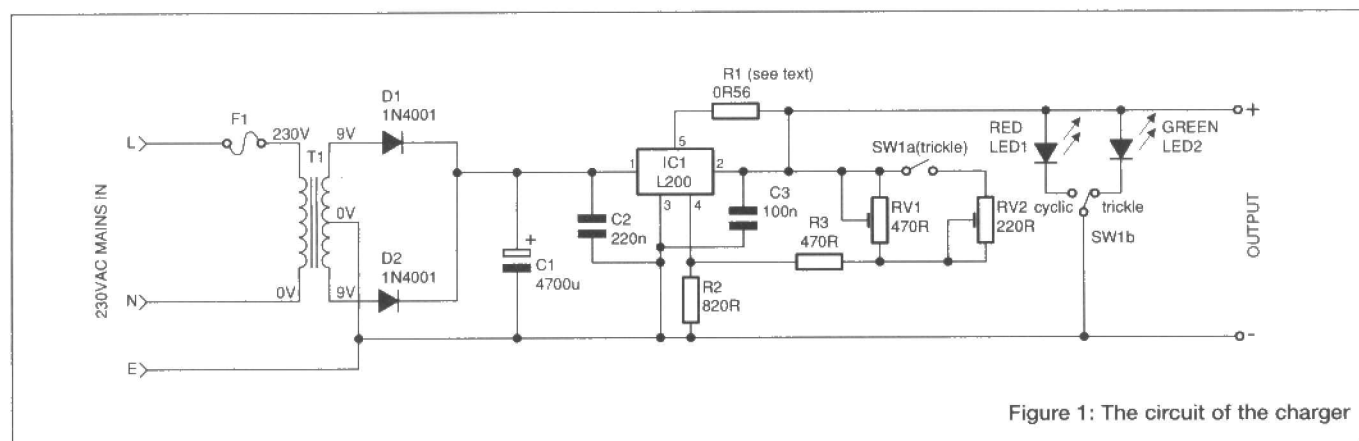


Figure 1: The circuit of the charger

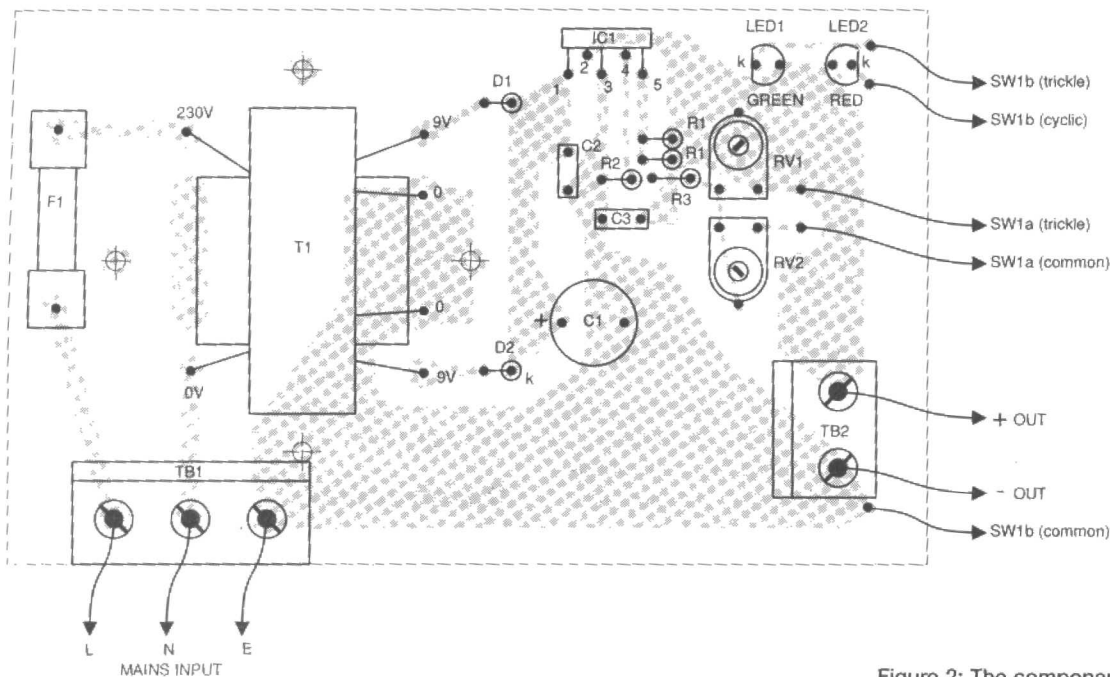
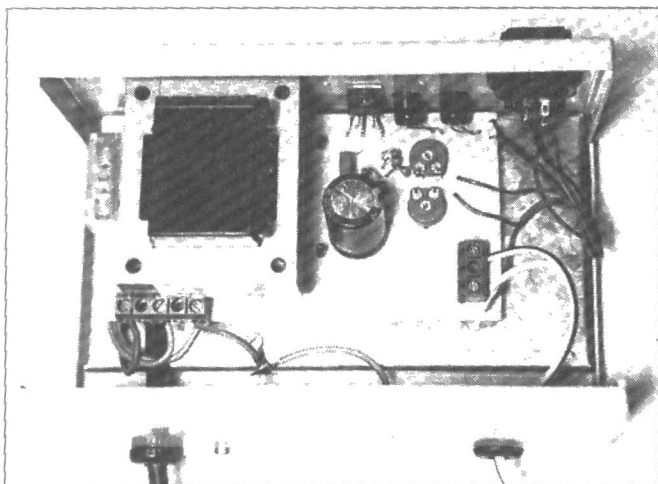


Figure 2: The component layout

The specified case has a separate internal chassis. Drill holes in this to correspond with those in the PCB and mount it temporarily on 12-mm plastic stand-off insulators. Drill a hole in the chassis close to TB1 position and attach a solder tag, to earth it later. Drill holes in the front of the enclosure for the charge selector switch, SW1, and for the LED clips, and in the rear panel for the mains input and output leads. Make the mains one large enough for a strain relief bush, and the output one sufficient for a rubber grommet. Drill a small hole nearby, scrape the paint away on the inside and attach a solder tag.



Place the chassis on the base of the box, so that IC1 is pressed against the front face. Bend its end leads as necessary to achieve this. Mark the outline of the tab and the position of the hole in it. At the same time, mark new positions of the chassis fixing-holes on the underside, since the chassis will now be in a different position to the one originally intended. Remove the chassis again and drill these holes. Scrape away the paint over the entire area of the IC1 tab to allow the free flow of heat to the case when it is fixed in position, as this is where all the heat sinking is. Mount the switch and LED clips.

Refer to figure 3 and make the switch connections carefully as shown. The specified switch has a red dot on the rocker for "on". Use this to indicate the cyclic position. Make up the input lead using a piece of 3A-rated 3-core mains wire. Secure it through the strain relief bush and, leaving some slack, attach it to terminal block, TB1, taking care to note which terminal is which. In the case of the earth wire, a second short wire of similar type should be included and this will be soldered to the solder tag on the chassis. Fit a plug on the other end of the mains lead. For a UK type, use a 2A or 3A fuse.

Place a 1A ceramic fuse in FS1 fuseholder and fit the insulating cover. The use of such a cover is essential for safety reasons. Note that this fuse MUST be rated for mains use and should NOT be of the glass type. Attach the PCB to the chassis, checking very carefully that all connections on the underside - especially the mains ones - are AT LEAST 5mm clear of the metal. Do not proceed until any corrections have been made and, if necessary, an insulating sheet has been placed between the PCB and the metalwork. Solder the free earth wire, together with a second piece of similar wire, to the solder tag on the chassis. Solder this further wire to the solder tag on the rear section of the case. Make certain that all earth connections are secure. This procedure ensures that the mains earth is reliably connected to both the chassis and to the external section of the case.

Attach the chassis inside the case and secure IC1 using a small nut and bolt through the hole drilled for the purpose. At the same time, manoeuvre the LEDs into their clips. Take care that their leads are not left touching one another and causing a short-circuit. Spread them as necessary using a small screwdriver. **Check that the fuseholder will be several millimetres clear of the top section of the case when this is fitted.**

Make up the output lead using a piece of twin wire such as loudspeaker type, kept as short as practicable (say, 50 cm) to avoid voltage drop. Fix a rubber grommet in the hole in the

case, pass the knot on the i. Attach the w that there is Attach the p the wire tak polarity - th be the posi polarity of t

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case, pass the wire through it and tie a knot on the inside to provide strain relief. Attach the wires to terminal block TB2 so that there is some slack left on the inside. Attach the power plug to the other end of the wire taking care to observe the polarity - the pin (inner) connection should be the positive one. This will match the polarity of the socket on the lamp.

The lamp itself

The following instructions are given as a general guide and cannot cover all details of every available lamp: constructors should be prepared to make small modifications as necessary to enable their own lamp to operate correctly.

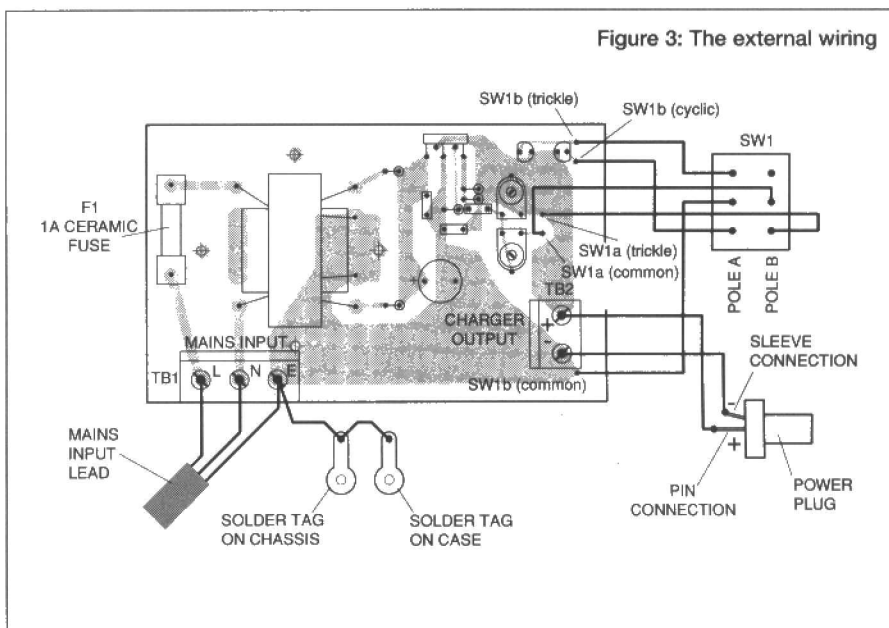
Warning: These lead acid cells are capable of delivering over 100A when short-circuited. This enormous current could cause insulation on wire to melt, burns to the skin and possible fire. Care must be taken at all times to prevent a short circuit. As a precaution, a fuse must be included as shown.

The existing "D" size alkaline cells are replaced by the cylindrical Cyclon lead acid ones which have practically the same diameter. These have both terminals on the top rather than one on the top and one on the bottom as with the "D" type. The lamp is powered using only two of these cells. Since the nominal voltage of a lead acid cell is 2V, the pair will provide a 4V supply instead of the nominal 6V given by the alkaline variety. The original bulb will probably have a rating of 4V8. This will allow for the voltage drop which occurs across the internal resistance of the alkaline batteries. The existing bulb must therefore be replaced by a 4V one, or it will be too dim. Use a quartz halogen lamp if this is available; otherwise use a Krypton type.

In the original arrangement, springy metal bridges at the bottom of the battery compartment connect the cells in series. Metal fingers at the top make contact with the batteries and bulb to make a circuit via the on-off switch. Begin by removing the metal bridges so that no metal parts exist at the bottom of the compartment. The cells may then be mounted upside down with the connecting wires soldered to the terminals. The fuseholder and a power-type input socket are attached on the side in the space occupied by one of the original cells. The position of these components must be chosen with care so that they will not interfere with any internal components or plastic strengthening ribs.

Identify the positive terminal of each cell - this is marked on the top. Begin by securing the two cells together using PVC tape so that they make a single rigid unit. Refer to figure 4. Using a short piece of stranded insulated wire, connect the positive terminal of one cell to the negative of the other so that they appear in series. Solder a wire between the fuseholder output (side) tag and either of the original battery connecting fingers. Solder a further wire from here to the centre (pin) connection of the charger input socket. Solder a piece of wire between the free negative terminal of the battery pack and other battery finger. Connect a wire from here to the negative (sleeve) tag of the charger socket. Finally, with the fuseholder empty, connect a wire between the free positive terminal of the battery pack and the fuseholder bottom tag.

Figure 3: The external wiring



Beam me up

It is essential to provide some ventilation for the cells. Drill one or two small holes near their position so that discharge gases can pass out (this could possibly happen under fault conditions). Insert the battery pack into position. Pack some thick foam plastic into the free space to hold it in place, but take care that this does not interfere with any of the connections at the fuseholder or charger socket. Make a thick cardboard insulator and place it on the metal bases of the cells so that the springy fingers, while making contact with the bulb and switch, are not short-circuited by the cases of the cells. Make any cut-outs as necessary so that the bulb-holding section fits correctly in place. Remove the bulb and replace it with the 4V one. Insert a 2A fuse in the fuseholder. Attach the reflector of the lamp and test for correct operation.

Setting up

The presets in the charger unit must now be adjusted to provide the correct operating voltages. For this, an accurate voltmeter (probably a digital one) will be needed, as it is necessary to adjust the voltages to within 0V1.

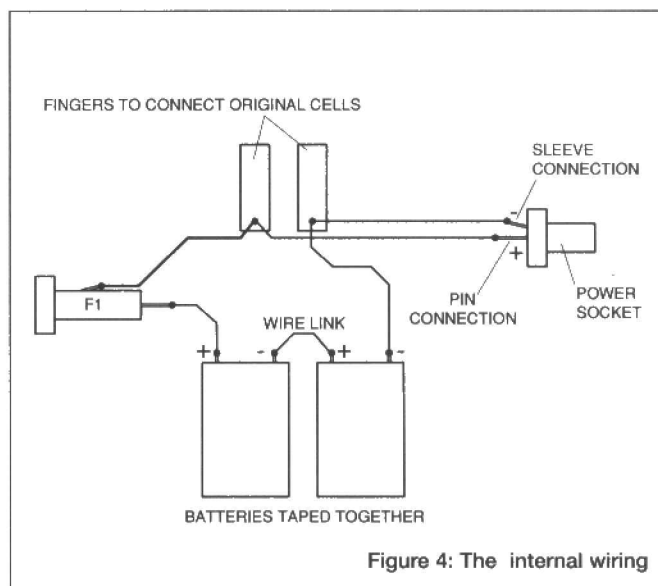


Figure 4: The internal wiring

Warning: Due to the danger of electric shock, exercise caution when operating the circuit with the top section of the case removed. Keep any screwdriver, etc. clear of terminal block, TB1.

Adjustments are made without connecting the lamp to the charger. To set the output voltages, simply hold the voltmeter test probes on to the screw heads of terminal block TB2. Under no circumstances hold them on the mains connections at TB1 by mistake.

Set the selector switch to cyclic and switch on. Check that the flashing red LED operates. If the green LED comes on instead, reverse the outer connections to SW1 pole B. With the aid of an assistant, adjust RV1 until the voltage lies between 4V8 and 5V1 (that is, between 2V4 and 2V55 per cell). Now set the selector switch to trickle and adjust RV2 until between 4V6 and 4V8 (2V3 to 2V4 per cell) is indicated. If the trickle and cyclic switch positions are reversed, remove the wire from the outer tag of SW1a and solder it to the other outer one instead.

Check the maximum current output as follows: set the meter to a high current range (1A minimum). Connect the probes direct to TB2 terminals as before. The reading should be about 800mA. Do not conduct this test for more than a few seconds at a time, because IC1 will become very hot and the case may find it difficult to conduct all the heat away. If the current is too large, it may be reduced by increasing the value of R1, and vice versa.

Battery charging

Note that the cells should be charged as soon as the bulb starts to dim in use. Do not allow them to become completely "flat" since they may be damaged. If they are run down so that the lamp becomes very dim or goes out, charge them immediately. In severe cases of discharge, it may take a long time for charging to take place and the cells may never recover completely.

One method is to leave the lamp on continuous trickle charge until needed, for instance, where a mains supply exists nearby. The alternative way is to give it a boost (cyclic) charge after a period of use. If the lamp has been used for 3 hours, the battery may be regarded as discharged to its useful limit, and it will then take about 24 hours to charge to 90% of its capacity in cyclic mode and longer on trickle. After this time, the charge increases very slowly to 100%. Do not leave the battery charging in cyclic mode for more than a few days. If left without charging, the cells should maintain more than half their charge for at least 6 months. If the lamp is not used, it

should therefore be given a cyclic charge of a few hours every few months to maintain its condition. It is normal for the case to become warm in the vicinity of IC1, especially when a poorly-charged battery is connected and therefore a large current is drawn.

Final point: When the lamp is connected to the charger, the LEDs will operate whether a mains supply exists or not. If there is no supply, the battery in the lamp will power the LEDs and impose a drain of about 20mA. If you wish to confirm that a supply exists, it would be necessary to fit a neon indicator in the mains input. This was not thought necessary on the prototype, however.

PARTS LIST For the Hand Lamp

Resistors

R1	1R (2 off) or single 0.56R resistor (see text)
R2	820R
R3	470R
RV1	470R min. horizontal preset
RV2	220R min. horizontal preset.

Capacitors

C1	4700u 16V radial electrolytic
C2	220n min metallised polyester, 5mm pin spacing
C3	100n min metallised polyester, 5mm pin spacing

Semiconductors

D1, D2	1N4001
LED1	5 mm red flashing LED for 3V5 to 13V operation without series resistor.
LED2	5 mm green LED for 5V operation without series resistor.
IC1	L200 voltage and current regulator in Pentawatt package.

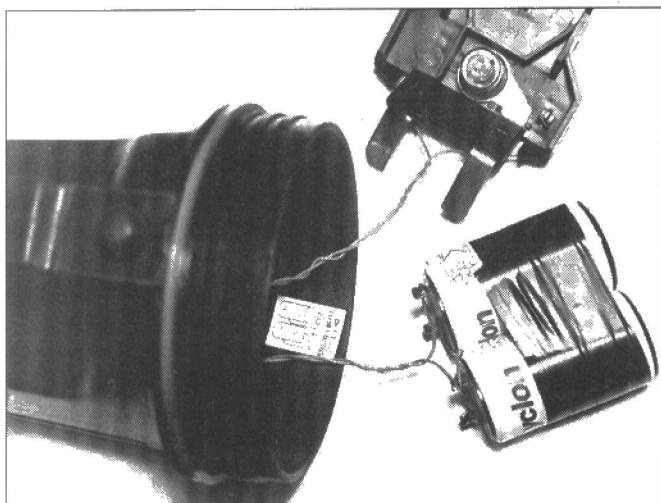
Miscellaneous

T1	12VA mains transformer with twin 9V windings.
SW1	Miniature DPDT rocker switch
TB1	PCB mounting screw terminal block: three terminals with 10mm spacing, rated for mains use.
TB2	PCB mounting screw terminal block: two terminals with 10mm spacing

PCB materials. Commercial hand lamp - see text. Two 2.5Ah Cyclon batteries. 4V pre-focus bulb rated at 800/850 mA to suit lamp - see text. 2.5mm power plug and single-hole fixing socket. 20 mm chassis-type fuseholder with insulating cover - 1A mains ceramic fuse to fit. 20 mm panel-type fuseholder - 2A glass fuse to fit. Strain relief bush, rubber grommet, two solder tags, small hardware. Aluminium case size: 150 x 100 x 75 mm.

Cyclon batteries are available from Electromail order code: 591-461. The case in the prototype is Maplin XY43W. Other components, including a suitable hand lamp (JU21X), are also available from Maplin. To order from Maplin phone 01702 554161.

Electromail: PO Box 33, Corby, Northants NN17 9EL. Tel: 01536 204555.

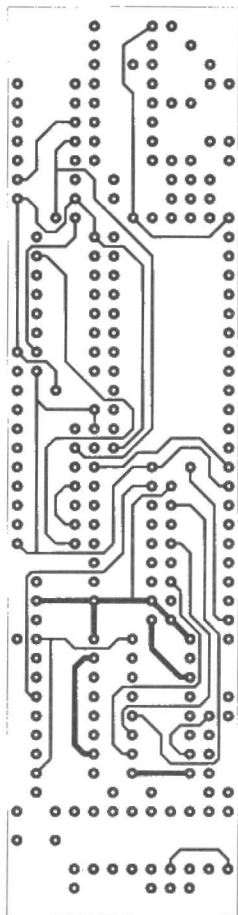


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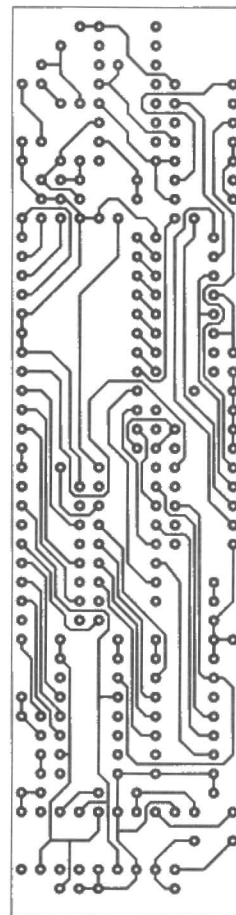
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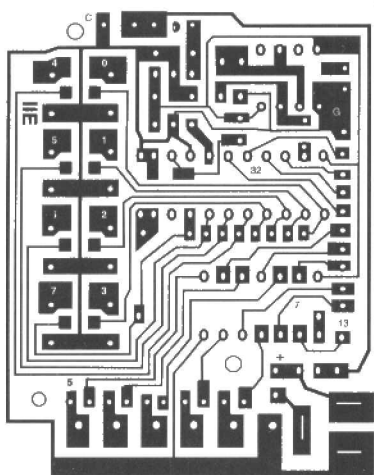
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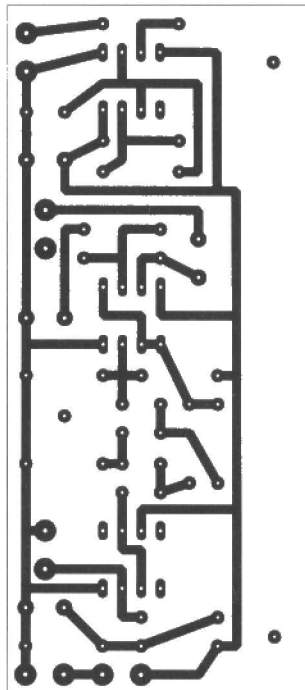
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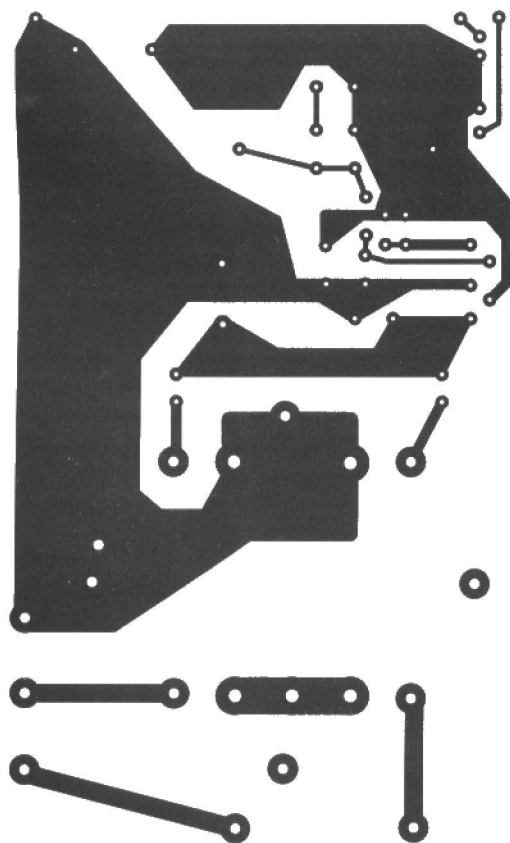
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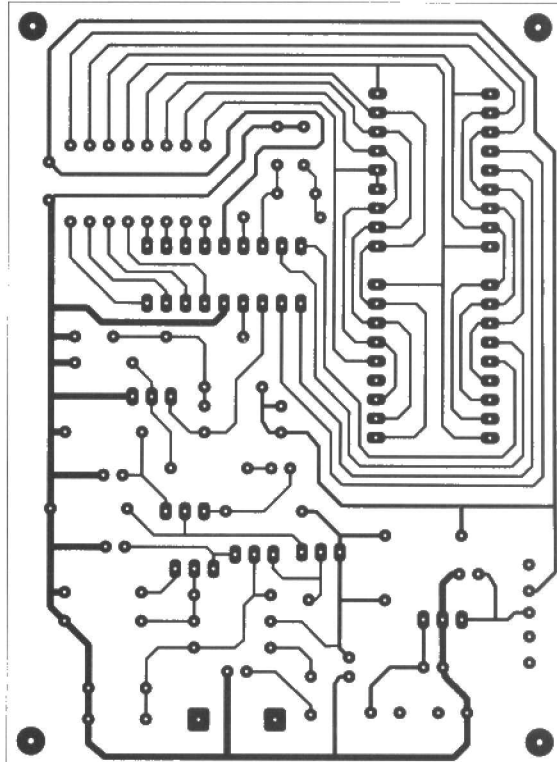
MINI-LAB DATA LOGGER



CABLE BREAK TESTER - JANUARY 1997



NEW LAMPS FOR OLD



LOW-COST DFM

Practically Speaking

BY TERRY BALBIRNIE

Over the last few episodes of *Practically Speaking* we have been looking at various aspects of connecting wire. This time we shall be looking at the subject of resistance wire.

Most wire used in amateur circuits is of the copper core type. This is because we usually wish it to have as low a resistance as possible to allow the free flow of current. Copper is second only to silver in this respect. The difference between these two metals is very small - copper has about 95% of the electrical conductivity of silver at normal room temperature.

Wind you own

Of course, there are many times when a high resistance is needed. Purpose-made resistors are then used and these are available very cheaply in a wide range of values. In an electronic circuit there will almost certainly be several of these.

Where a low value resistor is required (from a fraction of an ohm up to a few tens of ohms), it is

perfectly possible to make it yourself. For this, you will need a reel of resistance wire. This method could be appropriate to make a temporary resistor for experimental work before buying a commercial one of the correct value. A length of resistance wire could be tapped off using a pair of crocodile clips and the spacing between them adjusted to obtain the value required. The resistance may then be calculated or measured and the nearest standard value obtained.

Constant tan

There are various types of resistance wire and these are made from alloys (mixtures of metals). They are available in small amounts from the larger mail order suppliers. For given dimensions, these alloys have a much higher resistance than copper. There are two types which would be appropriate for use in amateur circuits.

The first, Constantan (sometimes called Eureka) has an almost constant resistance whatever its temperature, hence the name. It consists of about 60% copper and 40% nickel. Most materials (other than semiconductors) have a resistance which rises with temperature. The resistance of copper, for example, increases by about 50% between 0 degrees C and 100 degrees C. By comparison, Constantan, would vary by less than 0.5% over the same temperature difference. This material is useful for making standard resistors which will be guaranteed to have a certain value whatever the temperature of its surroundings. If a large current flows through the wire it will become warm.

Constantan wire may reach a temperature of up to 100 degrees C or so in normal use.

Another common type of resistance wire is Nichrome (nickel-chromium). This is an alloy consisting of nickel (80%) and chromium (20%) hence its name. Nichrome wire of a given length and diameter has a higher resistance than Constantan. Its chief advantage is that it can withstand being maintained red hot (up to 1100 degrees C) for long periods and is therefore useful for electric fire elements and similar applications. Constantan has a resistance of about 28 times that of copper and Nichrome some 60 times that of copper for wires of the same dimensions.

A bit hot

If the wire from which a resistor is to be wound is likely to become very hot, it is necessary to wind it on a heatproof tube although very short pieces could possibly be left supported in free air. Ceramic is the most usual material used. One source of this is the body of an old high-power resistor (see photograph). Constantan may be twisted into loops at the ends to secure it and copper connecting wires soldered to them.

The table below shows the resistance per metre of various gauges of copper, Constantan and Nichrome wire. (The topic of Standard Wire Gauge (SWG) was the subject of last month's *Practically Speaking*.) To make a resistor of a certain value, you should first select the type of wire to be used. It is then necessary to choose a thickness that will withstand the current flowing. The approximate current (in amps) required to raise the temperature of Constantan from room temperature to 100 degrees C and Nichrome to 500 degrees C is shown. The temperature would be reduced by using a thicker gauge of wire but then, of course, a greater length would be required for a given resistance. In practice, these temperatures will not be reached because the material on which the wire is wound will to some extent conduct the heat away. The length of wire needed is obtained by dividing the resistance needed by the "ohms per metre" figure.

That's all for this time. Next month we shall look at the subject of joining wires together.

SWG	COPPER ohms/m at 20 C	CONSTANTAN ohms/m I for 100 degrees (amps)	NICHROME ohms/m I for 500 degrees (amps)
20	0.026	0.745 5	1.65 8.5
22	0.043	1.23 3.5	2.72 6.3
24	0.070	2.00 2.5	4.40 4.5
26	0.105	3.00 2	6.60 3.5
28	0.155	4.40 1.5	9.70 2.7
30	0.221	6.30 1.4	13.9 2.2
32	0.292	8.30 1.2	18.3 2.0
34	0.402	11.4 1	25.2 1.5
36	0.589	16.7 0.8	37.0 1.3
38	0.945	27.0 0.7	59.0 1.0
40	1.480	42.0 0.6	92.0 0.8

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This month we have heard that the UK Government is launching a public campaign against "technofear".

Almost simultaneously, a report tells us that many old people don't trust their banks because of all this new technology, these hole-in-the-wall machines, you never know what it's going to do, do you? And what can you do about it if it does?

This may make your mind boggle. It makes my mind boggle. I thought "technofear" was a saying coined in the 1980s to explain why kids learn to use computers easily, but parents, teachers, captains of industry, and all the rest of them (apart from dedicated engineers) found themselves in difficulties from the word go. All this was a decade ago, and since then nearly every corner of our lives has been infiltrated by the long arm of the computer culture.

Yet we still have "technofear". Of course, it is the arrival of the Internet that has ushered in colourful new varieties of technofear, from the much touted terror that our society will collapse under the weight of pornography for which the Internet is somehow "to blame", to the less frequently discussed but much more widespread fear that office and household phone bills will spin out of control in the hands of "cyber skivers" glued to the Net when they should be doing their work - or their homework.

But we still have the other kind of technofear. People don't like computers for several reasons. Some folk are afraid of "breaking something". The recommended answer to this is "don't worry, go ahead,

you can't break anything. It's all saved."

This, of course, is fine in school or evening class, but as regular users know, the scope for confusion sown by a completely innocent beginner who gets into the wrong directory by some means unknown even to science and accidentally changes all the defaults - or simply deletes and overwrites something you really didn't want deleted - grows steadily as the amount of actual work done on computers mounts up.

I tell people that learning to use a computer - just to be a user, nothing more technical - is a bit like learning to drive a car. It's not all that complicated, but it takes a lot of time and patience, and is expensive, too, if you don't know where to get technical backup. (Users of certain helplines will laugh hollowly at this point.)

The same goes for learning how to use transistors, or logic gates, or microcontrollers. It takes time and practice. Kids have time to play around with the stuff (although they clearly prefer the quicker fix of a simulation program to the fiddly work of breadboarding). Older folk have to keep life in order, get results. Is it surprising that granny is disinclined to trust an Automatic Teller Machine with her life-savings, granted the reports we hear of the behaviour of some banks? It's not the machinery she fears, it's not knowing who to turn to for genuine help when something goes wrong.

So we applaud the efforts of the UK Government and other bodies contributing to the awareness campaign to banish technofear, but hope they realise that the anxiety will vanish when people find that IT is (a) useful and (b) not too full of booby traps for the unwary. It may be that we have a way to go yet.

The Challenge - Things that electronics hasn't fixed yet

Here's something practical: retailers hope that in time every item will be chip-coded, so that the supermarket checkout has only to interrogate your trolley to know exactly what you are purchasing, and charge you for it.

When can we have our valuables, semi-valuables, essentials etc. chip-coded, so that every time we lose our car keys, wire snippers, and mobile phone batteries we have only to ask our personal transponder and it will locate them instantly?

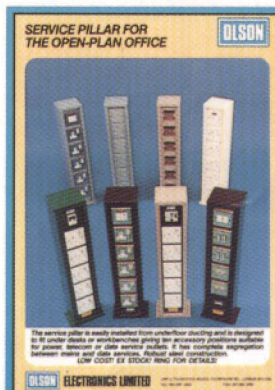
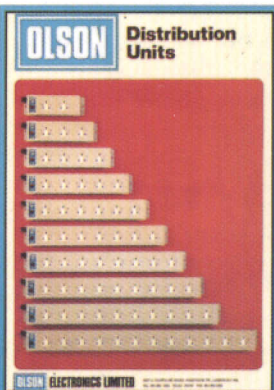
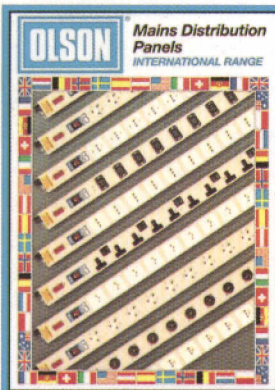
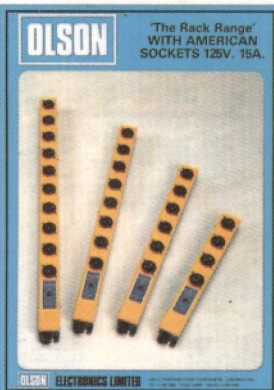
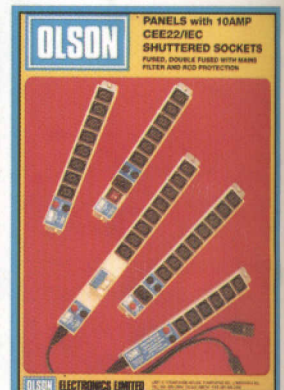
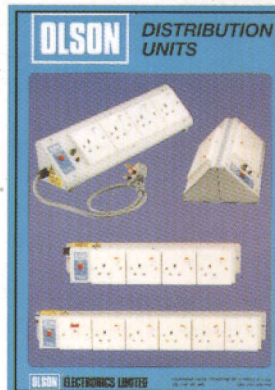
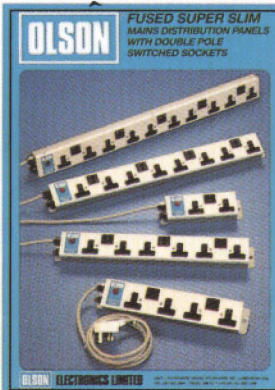
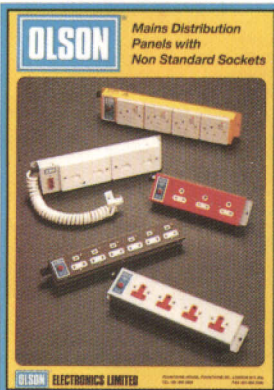
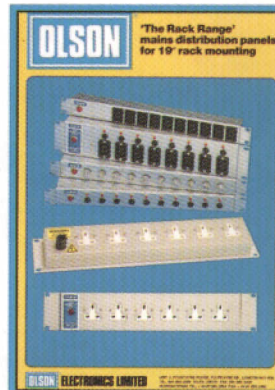
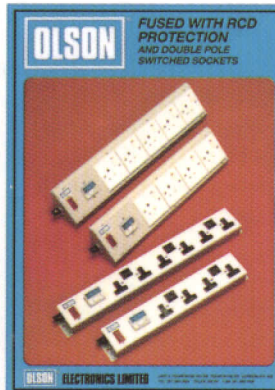
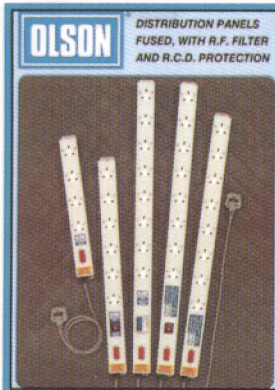
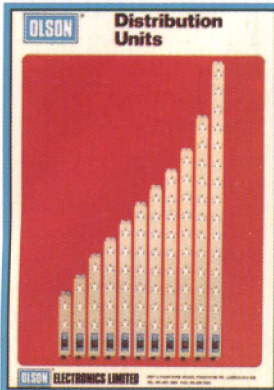
Next Month

In Volume 26, no. 3 of Electronics Today International, arriving at your newsagent in early March, we observe Experimenting with Video (Part 3) (the second half of the Mixer/Fader) ... Dr. Pei An has created a home automation computer/radio control system, and we start with digital radio building blocks ... Terry Balbirnie has been in the undergrowth locating hedgehogs, and Robert Penfold has been bending and shaping one of his famous music distortion effects. We also may have a solution to the cat and the goldfish-pond. And more ...

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